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TABLE OF CONTENTS

A REVIEW OF SEMICONDUCTOR ALLOYS	231
by Varadachari Sadagopan	
Table of Alloys	234
References	235

Abstracts of the Solid State Literature**Metallurgy and Chemistry of Solids**

Thermodynamic Properties of Elements and Alloys	238
General	238
Analysis	238
Phase Diagrams and Solid Solutions	238
Other Thermodynamic Properties	241
Crystal Structure	241
Crystal Lattices	241
Crystal Imperfections	242
Impurities	243
Non-Stoichiometry	244
Surface Structure	244
Structure of Special Crystal Forms	244
Structure of Specific Materials	244
Crystal Growth	245
Semiconductor Crystals	245
Ferrite and Ferromagnetic Crystals	245
Paramagnetic Materials	248
Crystal Surfaces (Including Surface Processing and Treatments)	248
Environmental Effects	249

Solid State Physics

General	249
Crystal Physics (Including Energy Band Structure)	250
Electrical Properties	251
Dielectric Properties	251
Carrier Properties	252
Conductivity	253
Superconductivity	256
Magnetoelectric (Galvanomagnetic) Properties	257
Electrical Properties of Surfaces	258
Electrical Properties of Specific Materials	258
Magnetic Properties	258
Ferro- and Ferrimagnetism	258
Paramagnetism	261

Optical Properties	263
General	263
Absorption (Transmission)	263
Luminescence	265
Photoelectronic Properties	266
Electromagnetic Properties	267
Optical Properties of Specific Materials	268
Thermal Properties	268
Mechanical Properties	269

Solid State Devices

Resistors	269
Diodes	270
Transistors	272
Photodevices	274
Thermal Devices	275
Magnetic Devices	275
Masers and Lasers	276

Basic Solid State Device Circuits

General	276
Amplifiers	277
Oscillators	280
Switching Circuits	281
Signal Converters	282
Wave Generators	282
Pulse Circuits	283
Other Solid State Device Circuits	283

Applications of Solid State Devices

Scientific and Medical	284
Aeronautical and Space	284
Radio and Television	285
Telephony, Telegraphy, and Telemetry	285
Microwaves and Ultramicrowaves	286
Recording and Reproduction	287
Computers	287
Power Applications	289
Control Applications	289
Instrumentation	290
Other Applications	292

New Products

Materials and Devices (Including Test and Fabri- cating Equipment)	292
Units and Systems	294

Subject Index	294
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Author Index	Inside Back Cover
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A REVIEW OF SEMICONDUCTOR ALLOYS

by

Varadachari Sadagopan

Department of Metallurgy

Massachusetts Institute of Technology

Cambridge 39, Massachusetts

Introduction

The rapid growth of the semiconductor industry has resulted in an increased demand for new materials with specialized properties to be used in device fabrication. This paper reviews the pertinent available data concerning the development of such new semiconductor alloys* and tabulates literature references for specific alloys.

General

After extensive investigations on the production and properties of elemental semiconductors, researchers began to explore the semiconducting properties of AlIIBV^1 , AlIIBVI , and $\text{A}_2\text{IIIB}_3\text{VI}$ compounds. These compounds have been shown to possess either a defect zincblende or defect antifluorite structure². Austin and Sheard³, Bowers et al⁴, and Scanlon⁵ have studied non-stoichiometry in semiconducting compounds and its effect on semiconducting properties. The development work in the field of non-crystalline, amorphous and liquid electronic semiconductors has been reviewed by Ioffe and Regel⁶. A related study on the textural properties of germanium film has been given by Davey⁷.

A large amount of work has also been done in studying semiconducting alloys formed between two or more semiconducting elements or compounds. The interest in these systems is centered on the fact that the properties of alloys formed as a solid solution can be varied over a continuous range of values. Thus a range of electronic energy levels, lattice vibrational states, and electrical, magnetic and thermal properties can be realized as a function of composition of the semiconducting alloy. Besides a continuous variation of these structure-sensitive properties with composition, systems with rare properties are occasionally encountered; for instance, Blum and Regel¹⁸ have found that the carrier mobilities of HgSe-HgTe solid solutions are higher than those of either HgSe or HgTe .

Work done in semiconductor alloys up to 1957 has been reviewed by Herman et al⁹. Since then many binary, quasibinary, ternary, and more complex systems have been studied by a number of workers in different laboratories using various experimental techniques. Most of the work has been done with an x-ray powder camera, the advantages and limitations of which have been described by Azaroff and Buerger¹⁰. Otte¹¹ has described an extension of the use of the Debye-Scherrer method on an x-ray spectrogoniometer. Electron probe microanalyzers¹² have also been used to a limited extent to study semiconductor alloys. Because of its sensitivity in microanal-

In this review "alloy" is restricted to homogenous, disordered, substitutional solutions.

ysis and high resolution, the microanalyzer shows promise for the measurement of concentration profiles in various systems, thereby providing a means of obtaining information about diffusion constants, dopant interactions, and solid solubilities.

Studies on the x-ray scattering due to order-disorder phenomena in metallic solid solutions in equilibrium have been reviewed by Guinier¹³. Smirnov and Tikhonova's¹⁴ work on the theory of scattering of x-rays and thermal neutrons by multicomponent substitutional alloys is also of interest for future development in this field.

Since a continuous variation of semiconducting properties with chemical composition is encountered only in cases where there is solid solubility, it is worth while to postulate conditions under which complete solid solubility between semiconducting compounds is attained. The following four conditions have been observed to be necessary: 1) compounds must have identical crystal lattices, 2) chemical bonds and the atoms in each unit must be similar, 3) two compounds must have one kind of atom in common, and 4) component atoms must be capable of forming continuous solid solution.

When one or more of the above conditions is not satisfied, only limited solid solubility between the compounds is obtained^{15,16}. In some cases, due to favorable conditions at certain stoichiometric compositions (2:1 and 1:2 in $\text{Bi}_2\text{Te}_3\text{-Sb}_2\text{Te}_3$), order sets and singularities in certain properties result¹⁷.

Semiconducting Solid Solutions

Formed Between Elements

The interest in semiconductor alloys formed between two or more semiconducting compounds originated in the work done in the Ge-Si system by Stohr and Klemm¹⁸, Wang and Alexander¹⁹, Johnson and Christian²⁰, and Mitrenin et al²¹. This work has been invaluable in giving a general understanding of the electronic structure and semiconducting properties of alloys.

It has been determined that Ge-Si alloys are substitutional and maintain the diamond cubic structure. The distribution of solute atoms in the solvent lattice has been observed to be random. Interesting studies on the change of energy gap with composition and a speculation on the energy band structure in these alloys have been made by Herman²², Levitas²³, and Tauc and Abraham²⁴.

*Accurate formulation of rules to predict mutual solid solubility among these compounds has to await further work. Until then these rules serve a useful purpose in the understanding of general trends in solubilities.

Compounds formed by other elements with Ge and Si have been described by Hansen²⁵. A systematic study of the way in which they affect the band structure of Ge and Si has yet to be attempted.

Electrical properties of Se-Te alloys and the changes in energy band due to alloying have been investigated by Nussbaum²⁶. Smorodina²⁷ has studied the Te-Se system with x-rays. Alloys in this system have been shown to crystallize in a hexagonal lattice. Studies have failed to reveal the presence of long range order in the system and have also shown that Te-Se alloy is not a simple substitutional or interstitial alloy.

Solid Solution Between $A^{III}B^V$ Compounds

$A^{III}B^V$ compounds have a zincblende structure and satisfy the conditions necessary for mutual solid solubility; as a result, one would expect complete solid solubility between these compounds. Early work by Shih and Peretti^{28,29}, Köster and Thoma³⁰, Goryunova and Federova³¹, Kolm et al³², and Blakemore³³ did not support this expectation. However, studies by Folberth³⁴ in the systems InAs-InP and GaAs-GaP, and Woolley et al^{35,36} in the systems GaSb-InSb and GaAs-InS, have shown that complete solid solution can be obtained if equilibrium is achieved by prolonged annealing at correct temperatures. More recently Woolley and Smith³⁷ have shown conclusively that in almost all cases of $A^{III}B^V$ compounds complete solid solution exists throughout the entire range of composition provided care is taken to attain equilibrium. They also have found that Vegard's law is generally obeyed in these systems and that the alloys formed have a zincblende structure. They have investigated the nature of the solidus curves and the possibility of the occurrence of low temperature miscibility gaps for a number of $A^{III}B^V$ solid solutions and they have pointed out the advantages of slow zone recrystallization or slow directional freezing methods to aid solid specimens in attaining equilibrium. Goryunova et al³⁸ have explored the advantages of annealing alloys under pressure in the InAs-In₂Se₃ system. They have found that by a proper selection of optimum conditions for temperature and pressure, homogenization of semiconductor alloys can be brought about in a shorter time than that required by other methods. (The technique of annealing under pressure has not often been employed by researchers outside of the U.S.S.R.)

Ivanov-Omskii and Kolomiets³⁹ have explored the discrepancy between early and recent work regarding the extent of solid solubility of these compounds. They have commented that impediments to diffusion exist in these compounds due to their pronounced covalent character, which in turn hinders isomorphic substitution. Differences in the solid solubility of these compounds were found to be caused by alloys which were in different states of equilibrium. They have shown how equilibrium can be attained in an InSb-GaSb system by using a zone melting technique and by controlling the rate of zone motion. Progressive casting (normal freezing technique) and zone casting at various rates of crystallization have been used by Miller et al⁴⁰ in an attempt to establish equilibrium in the quasibinary system of AlSb-GaSb solid solution alloys.

Romanenko and Ivanov-Omskii⁴¹ have studied some of the thermodynamic aspects of $A^{III}B^V$ alloys to gain an understanding of their stability and the variation of their properties with alloying.

Solid Solution Between $A^{II}B^{VI}$ Compounds

Interest in the solid solution between $A^{II}B^{VI}$ compounds has increased in the last eight years. Krehmeller et al⁴² have studied hydrothermally prepared solid solutions of ZnS-HgS, CdS-HgS and ZnS-CdS. Complete solid solutions have been obtained over the whole range for the ZnS-HgS and HgS-CdS systems. However, in the HgS-CdS system the crystal structure of the solid solution has been shown to be a function of the composition. In the 0-43 mole per cent HgS range Wurtzite structure has been reported; above 60 mole per cent cubic structure exists in the 43-60 mole per cent hexagonal and cubic structures coexist. Kornilov⁴³ has also studied the ZnS-CdS system and has reported complete solid solubility between the two compounds.

Another important study is concerned with the formation of solid solution in $A^{II}B^{VI}$ tellurides. Goryunova and Fedorova⁴⁴ have detected occurrence of solid solution in the CdTe-ZnTe system. Kolomiets and Malkova⁴⁵ have measured the change in lattice parameter with composition for this system and have studied the semiconducting properties of these alloys. Nikolskaya and Regel⁴⁶ have made similar measurements in the HgSe-HgTe system. Woolley and Ray⁴⁷ have studied solid solutions in the three systems CdTe-HgTe, CdTe-ZnTe, and HgTe-ZnTe, and have confirmed the earlier findings that solid solution occurs at all compositions in each system. The change in lattice parameter with composition has been determined in each case. X-ray methods were used by these authors to study the form of the solidus curve. They did not find evidence for the existence of either ordering or miscibility gaps down to 500°C in any of the three systems.

In the above studies solid solutions resulted from isovalent isomorphism between the component compounds. A study of the heterovalent isomorphism in the crystallochemical group diamond-zincblende-Wurtzite has been made by Goryunova and Fedorova⁴⁸ in the system ZnSe-GaAs. Efforts to achieve a heterovalent substitution by the simultaneous replacement of Ga by Zn and As by Se have met with success. Vegard's law has been shown to be obeyed in such solid solution and the existence of heterovalent isomorphism has been confirmed.

Solid Solutions Between $A_2^{III}B_3^{VI}$ Compounds

$A_2^{III}B_3^{VI}$ compounds possess a zincblende structure like most of the $A^{III}B^V$ and $A^{II}B^{VI}$ compounds. Hence, an extension of the studies on the formation of solid solution between $A^{III}B^V$ and $A^{II}B^{VI}$ compounds has been carried out for $A_2^{III}B_3^{VI}$ compounds by various researchers.

The $A_2^{III}B_3^{VI}$ compounds have been shown to have the defect zincblende structure⁴⁹ or a defect antifluorite structure² with vacancies in every third site of the A sublattice. The lattice vacancies are distributed at random on the A sublattice when the $A_2^{III}B_3^{VI}$ compound is prepared under normal conditions. However, these vacancies can be ordered, as shown by the work of Hahn⁵⁰ and Inuzuka and Sugaike⁵¹. Such an ordering affects the conduction properties of the material and thereby the basic parameters like lattice vibration spectrum, Brillouin zone form, etc. Goryunova² and Borshchevskii et al⁵² have shown that these compounds occupy an intermediate position between the corresponding isoelectronic compounds $A^{III}B^V$ and $A^{II}B^{VI}$ with respect to their microhardness and forbidden zone width.

The formation of substitutional solid solutions in semiconducting compounds with defect zincblende structure has been discussed by Goryunova and Grigor'eva⁵⁴, Grigor'eva⁵⁵, Woolley and Smith⁵⁶, and Rosenberg and Strauss⁵⁷. In the first paper, occurrence of considerable solid solution in the systems Ga_2Te_3 - In_2Te_3 , $\text{GaAs-Ga}_2\text{Se}_3$, $\text{ZnSe-Ga}_2\text{Se}_3$, and $\text{ZnTe-Ga}_2\text{Te}_3$ has been reported. In the second paper, a report of study on the quaternary system $(\text{Ga}_x\text{In}_{1-x})_2\text{Te}_3$ has been made. Substitutional solid solutions over a wide range of composition have been observed in this system. The third paper describes studies on Ga_2Te_3 - In_2Te_3 , and Ga_2Se_3 - Ga_2Te_3 systems. In the former, solid solutions have been obtained at all compositions throughout the alloy range, with the alloys having the usual zincblende structure. In the system Ga_2Se_3 - Ga_2Te_3 , Woolley and Smith have reported the occurrence of ordering for 25 and 30 mol percentage Ga_2Te_3 . The similarities between this ordering and ordering in chalcopyrite has been pointed out by the authors. Rosenberg and Strauss have studied the results of extensive substitution of Sb and Bi atoms in Sb_2Te_3 and Bi_2Te_3 by indium atoms. They have reported a decrease in lattice parameter and mobility consequent to such a substitution; however, the carrier concentration has been found to be unaffected.

Thus the studies on $\text{A}_2\text{III}\text{B}_3\text{VI}$ compounds closely resemble the results obtained for AIIIBV compounds in that appreciable solid solution occurs in a number of cases over the whole range of composition. The additional factor of interest arises from the presence of lattice vacancies in these compounds which has been shown to influence semiconducting properties. The semiconducting alloys formed between these $\text{A}_2\text{III}\text{B}_3\text{VI}$ compounds are of particular interest due to their promise as thermoelectric materials.

Solid Solubility of AIIIBV Compounds in Compounds of the $\text{A}_2\text{III}\text{B}_3\text{VI}$ Type

Another type of study has been concerned with alloys formed between AIIIBV and $\text{A}_2\text{III}\text{B}_3\text{VI}$ compounds, both of which have the zincblende structure. The chief interest in this study is to observe the effect of AIIIBV on the lattice vacancies in $\text{A}_2\text{III}\text{B}_3\text{VI}$ compounds. The vacancies can be either systematically filled by alloying with AIIIBV compounds or ordered by choosing proper alloys. Woolley and Smith⁵⁶ have found that solid solution appears to take place between AIIIBV and $\text{A}_2\text{III}\text{B}_3\text{VI}$ compounds when the AIIIBV compound is an arsenide but not when it is an antimonide. Structures other than zincblende have been shown to result in the latter case.

Goryunova⁵² first studied the occurrence of extensive solid solutions of $\text{GaAs-Ga}_2\text{Se}_3$ but did not give further details. Goryunova and Grigor'eva⁵⁴ next studied the arsenoselenides of gallium ($\text{GaAs-Ga}_2\text{Se}_3$) in detail. Complete substitutional solid solution in the system was reported. In the gallium arsenoselenides studied, a gradual replacement of As by Se with corresponding vacancies in Ga lattice sites was anticipated. Woolley and Smith⁵⁶ have studied $\text{InAs-In}_2\text{Te}_3$, $\text{GaAs-Ga}_2\text{Te}_3$, $\text{GaAs-Ga}_2\text{Se}_3$, $\text{InSb-In}_2\text{Te}_3$, $\text{GaSb-Ga}_2\text{Te}_3$, and $\text{GaSb-Ga}_2\text{Se}_3$ systems. Long annealing times were required to attain equilibrium in these systems. Goryunova et al^{58,59} have suggested a technique of annealing under pressure in order to achieve homogenization in less time.

Goryunova and Radautsan⁶⁰ have studied the solid solutions formed in the $\text{InAs-In}_2\text{Te}_3$ system. Their results indicate that solid solutions with sphalerite structure are formed in the en-

tire range of concentrations. Their results also reveal that outside the $\text{InAs-In}_2\text{Se}_3$ section there is only a narrow field of solid solution in the In-As-Se system.

Radautsan⁶¹ has studied the section $\text{InAs-In}_2\text{Se}_3$ in the ternary system In-As-Se and has confirmed earlier results. Hahn and Thiele⁶² have studied the systems In_2Se_3 - InP , In_2Se_3 - InAs , In_2Te_3 - InSe-InAs , and InTe-InAs with x-rays. They have observed mixed crystal phases of the zincblende type in all systems and have determined that this results from the tendency of In to form tetrahedral coordination in compounds with nonmetals.

Woolley et al⁶³ have determined the range of solid solution at the InSb end of the $\text{InSb-In}_2\text{Te}_3$ phase diagram. This is in agreement with their previous findings that in alloys containing Sb, the zincblende structure is lost and limited solubility results.

A complete x-ray study of the ranges of solid solubility of In_2Se_3 in some compounds with zincblende structure (InAs , InSb , In_2Te_3 , and Ga_2Te_3) has recently been reported by Woolley and Keating⁶⁴. Ordering effects have been observed in the $\text{InAs-In}_2\text{Se}_3$ system but the structure of the ordered phase has not been determined. In the In_2Te_3 - In_2Se_3 system ordering of lattice vacancies similar to that of In_2Te_3 has been found. In the Ga_2Se_3 - In_2Se_3 system, blurring of x-ray powder lines has been observed. This is associated with the presence of stacking faults occurring in the alloys and in Ga_2Se_3 itself. Patterson⁶⁵ has obtained similar blurring due to stacking faults in zinc sulfide powder lines.

Limited work has been done in solid solutions formed between AIIIBV and $\text{A}_2\text{III}\text{B}_3\text{VI}$ compounds. The systems $\text{ZnSe-Ga}_2\text{Se}_3$ and $\text{ZnTe-Ga}_2\text{Te}_3$ have been studied by Goryunova⁵² while Goryunova et al^{58,59} and Woolley and Ray¹⁶ have studied the formation of solid solutions in $\text{CdTe-In}_2\text{Te}_3$ and $\text{HgTe-In}_2\text{Te}_3$ and $\text{HgTe-In}_2\text{Te}_3$ systems.

Miscellaneous Semiconductor Alloys and Complex Alloy Systems

References to the large amount of work reported for semiconductor alloys which do not strictly come under one of the above classifications are given in the table at the end of the text. Due to the variety and volume of the work, a detailed review has not been undertaken.

A partial list of some of the complex semiconductor alloy systems studied has also been provided. Useful knowledge on the methods of preparation and the nature of bonding in these complex compounds has been obtained by these studies.

Conclusion

Although we are not at present in a position to predict precisely the fundamental properties of semiconductors (energy gap, carrier mobilities, etc.), the work done in the field of semiconductor alloys has been of utmost importance in predicting the trends to be expected in a given family of semiconductors.

TABLE OF ALLOYS

Binary Systems:	Reference	InAs-InP	34, 70, 75	Sn-GaAs	32
Ga-As P-T-X Phase Diagram	66	InAs-InSb	28, 29, 31, 37, 44	Sn-InAs	32
Ge-Al	18			Sn-InSb	74
Ge-Ag	67	Between A ^{III} B ^V and A ^{III} B ^{VI} Compounds:		Between A ^{IV} B ^{VI} Compounds:	
Ge-Si	18, 20, 21, 22, 23, 24	InAs-InSe	62	PbSe-PbTe	84
Ge-Sn	18	InAs-InTe	62	PbTe-SnTe	84
Ge-x	25	InSb-InTe	86	Between A ^{IV} B ^{VI} and A ₂ ^{IV} B ₃ ^{VI} Compounds:	
Ge-U	68	Between A ^{III} B ^V and A ₂ ^{III} B ₃ ^{VI} Compounds:		PbTe-Sn ₂ Te ₃	104
In-As P-T-X Phase Diagram	66	AlSb-Al ₂ Te ₃	80	Between A ^{IV} B ^{VI} and A ₂ ^V B ₃ ^{VI} Compounds:	
In-P	69	GaAs-Ga ₂ Se ₃	52, 54, 56	PbTe-Bi ₂ Te ₃	104
In-P P-T-X Phase Diagram	66	GaAs-Ga ₂ Te ₃	56	Between A ₂ ^V B ₃ ^{VI} Compounds:	
Se-Te	26, 27	GaSb-Ga ₂ Se ₃	56	As ₂ Se ₃ -Sb ₂ Se ₃	88
Si-x	25	GaSb-Ga ₂ Te ₃	56	Bi ₂ Se ₃ -Sb ₂ Se ₃	89
Between A ^{II} B ^{VI} Compounds:		InAs-In ₂ Se ₃	38, 53, 60, 61, 62, 64, 81, 82	Bi ₂ Se ₃ -Bi ₂ Te ₃	3, 83, 84, 92, 100, 107
CdS-HgS	42			Bi ₂ Te ₃ -Sb ₂ Se ₃	3, 92
CdS-ZnS	42, 43	InAs-In ₂ Te ₃	56, 60, 62	Bi ₂ Te ₃ -Sb ₂ Te ₃	17, 57, 84, 90, 91
CdTe-HgTe	44, 47, 76	InP-In ₂ Se ₃	62	Between A ^{VI} and A ^{III} B ^V Compounds:	
CdTe-ZnTe	44, 45, 47	InSb-In ₂ Se ₃	64	Te-InSb	86
HgS-HgSe	8, 46, 77, 78, 79	InSb-In ₂ Te ₃	56, 63	Miscellaneous Systems:	
HgS-HgTe	46, 79	Between A ₂ ^{III} B ₃ ^{VI} Compounds:		I-V-VI ₂ Compounds	99
HgS-ZnS	42	Ga ₂ Se ₃ -Ga ₂ Te ₃	56	II-IV-V ₃ Compounds	108
HgSe-HgTe	8, 46, 77, 78, 79	Ga ₂ Se ₃ -In ₂ Se ₃	64	V-VI-VII Compounds	96
HgTe-ZnTe	47	Ga ₂ Te ₃ -In ₂ Te ₃	2, 55, 56	Mg ₂ Ge-Mg ₂ Sn	87
Between A ^{II} B ^{VI} and A ^{III} B ^V Compounds:		In ₂ Se ₃ -In ₂ Te ₃	64	AgAsSe ₂	101
ZnSe-GaAs	48	Between A ^{III} B ₃ ^{VI} and A ₂ ^{III} B ₃ ^{VI} Compounds:		AgAsTe ₂	101
Between A ^{II} B ^{VI} and A ₂ ^{III} B ₃ ^{VI} Compounds:		InTe ₃ -Ga ₂ Te ₃	103	AgBiS ₂	98
CdTe-Ga ₂ Te ₃	105	Between A ^{III} B ^{VI} and A ^{IV} B ^{VI} Compounds:		AgSbTe ₂	98
CdTe-In ₂ Te ₃	16	InTe-PbTe	15	AgSbSe ₂	98
HgTe-Ga ₂ Te ₃	105	InTe-SnTe	15	Al-In-Sb	30
HgTe-In ₂ Te ₃	16	Between A ₂ ^{III} B ₃ ^{VI} and A ₂ ^V B ₃ ^{VI} Compounds:		Al-Ga-Sb	30
ZnSe-Ga ₂ Se ₃	52, 58, 59	Tl ₂ S-Sb ₂ S ₃	89	As-S-Te	85
ZnTe-Ga ₂ Te ₃	52, 58, 59, 105	Tl ₂ Se-As ₂ Se ₃	88	As-Se-Te	85
Between A ^{II} B ^{VI} and A ^{IV} B ^{VI} Compounds:		Tl ₂ Se-Sb ₂ Se ₃	97	Bi ₂ Se _x Te _{3-x}	3, 83, 84
CdTe-PbTe	15	Tl ₂ Se-Sb ₂ Te ₃	88	Ga-In-Sb	30
CdTe-SnTe	15	Between A ₂ ^{III} B ₃ ^{VI} and A ₂ ^V B ₃ ^{VI} Compounds:		InAs _{1-x} P _x	4
Between A ^{III} B ^V Compounds:		In ₂ Te ₃ -Bi ₂ Te ₃	57	In-As-Sb	29
AlSb-GaSb	30, 40, 70, 71	In ₂ Te ₃ -Sb ₂ Te ₃	57	In-As-Se	61
AlSb-InSb	30, 70	Between A ^{IV} and A ^{III} B ^V Compounds:		Pb _{0.91} Cd _{0.09} Te	15
GaAs-GaP	34	Ge-GaAs	32	Pb _{0.97} In _{0.03} Te	15
GaAs-GaSb	31	Ge-GaSb	106	Sn _{0.97} In _{0.03} Te	15
GaAs-InAs	31, 36, 37, 72	Ge-InAs	32	Tl-Se-Te	102
GaSb-InSb	30, 31, 32, 33, 35, 37, 39, 40, 41, 70, 73, 74	Ge-InSb	74	Higher Order Systems:	
		Pb-GaAs	32	CuPbAsS ₃	101
		Pb-InAs	32	AlSb-GaSb-InSb	30
		Si-GaAs	32	AgSbSe ₂ -AgSbTe ₂ -AgBiSe ₂ -AgBiTe ₂	94
		Si-InAs	32	AgSbSe ₂ -AgSbTe ₂ -AgBiSe ₂ -PbSe-PbTe	95

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ABSTRACTS OF THE SOLID STATE LITERATURE

METALLURGY AND CHEMISTRY OF SOLIDS

THERMODYNAMIC PROPERTIES OF ELEMENTS AND ALLOYS

GENERAL

11,246 A REVIEW OF SEMICONDUCTOR ALLOYS by V. Sadagopan (MIT); Solid State Abstracts, Vol. 2, pp. 231-237, Aug./Sept. 1961

Recently published work on homogeneous, disordered, substitutional solutions with semiconducting properties is reviewed. References on 111 specific alloys are cited.

ANALYSIS

11,247 CONCERNING THE THEORY OF THE SCATTERING OF X-RAYS AND THERMAL NEUTRONS BY MULTICOMPONENT SUBSTITUTIONAL ALLOYS by A. A. Smirnov and E. A. Tikhonova (UKr. SSR Acad. Sci.); Soviet Phys.-Solid State, Vol. 1, pp. 1277-1284, 1960

Changes of x-ray and slow neutron scattering caused by lattice distortion resulting from varying atomic radii in alloys are discussed. Rigorous calculations are presented for both direct refraction and background intensities for binary and ternary disordered substitutional alloy crystals. An elastic continuum model is used and monochromatic x-rays are assumed.

Analysis of:

Ge-Si Alloys - See 11,334 and 11,337

GaAs-GaSe Alloys - See 11,266

Ga₂Te₃-In₂Te₃ Alloys - See 11,267

PHASE DIAGRAMS AND SOLID SOLUTIONS

11,248 CONSTITUTION OF BINARY ALLOYS by M. Hansen, McGraw-Hill, 1958, 2nd Edition (English Revised Edition of "Der Aufbau der Zweitoeffegierungen," 1936)

A definitive catalogue of physical data and reference sources concerning binary alloys is presented. The second edition in-

cludes 1334 entries and 9800 literature references through 1955. Phase diagrams, crystal structure information, and summaries of the most important research methods and findings are included.

11,249 THE SYSTEM OF InAs-InSb by C. Shih and E. A. Peretti (U. Notre Dame); J. Am. Chem. Soc., Vol. 75, pp. 608-609, Feb. 1953

A phase diagram for the system InAs-InSb obtained by thermal analysis, x-ray, and metallographic studies is presented. The liquidus runs in an uninterrupted line from the freezing point of InAs (950°C) to a eutectic point experimentally indistinguishable from the freezing point of InSb (525°C). In the solid state a small single phase region exists near the InAs end of the diagram.

11,250 THE PHASE DIAGRAM OF THE SYSTEM InAs-Sb by C. Shih and E. A. Peretti (U. Notre Dame); AIME, Vol. 46, pp. 389-396, 1954

The phase diagram for the system InAs-Sb obtained by thermal analysis, metallographic and x-ray techniques is presented. A eutectic is formed at 582°C, containing 82.5 per cent Sb and 17.5 per cent InAs by weight; it consists of Sb plus a solid solution containing about 2.5 per cent Sb.

11,251 CONSTITUTION OF THE AgSbSe₂-AgSbTe₂-AgBiSe₂-AgBiTe₂ SYSTEM by J. H. Wernick, S. Geller, and K. E. Benson (Bell Labs.); J. Phys. Chem. Solids, Vol. 7, pp. 240-248, 1958

A determination of the six pseudo-binary phase diagrams in the semiconducting system AgSbSe₂-AgSbTe₂-AgBiSe₂-AgBiTe₂ is reported. Complete series of solid solutions with the cubic structure exist in this pseudo-quaternary system. The locus of temperatures and compositions for the order-disorder transition has been determined. Lattice constants as a function of composition for the cubic phase and thermoelectric power data for some of the solid solutions are presented.

11,252 PHASE DIAGRAM OF THE PSEUDO-BINARY SYSTEM Bi₂Te₃-Sb₂Te₃ by J. R. Weise and R. Pyle (Franklin Inst. Labs.) J. Metals, Vol. 12, p. 720 (A), 1960

It was reported that the semiconductor compounds Bi₂Te₃ and Sb₂Te₃ are isomorphous, with a rhombohedral (C_{3i}) structure. X-ray analysis, using powder techniques, indicates that these compounds are soluble in each other in all proportions. Cooling curves, obtained at 10 mole pct. composition intervals by conventional thermal analysis techniques, indicate that the liquidus and solidus of the system are very nearly congruent. The solidus compositions were confirmed by polarographic analysis.

11,253 THE THERMODYNAMICS OF SOLID SOLUTIONS OF CERTAIN SEMICONDUCTOR SYSTEMS by V. N. Romanenko and V. I. Ivanov-Omskii (USSR Acad. Sci.); Soviet Phys.-Doklady, Vol. 4, pp. 1342-1344, 1960

Experimental and theoretical phase change temperature vs alloy concentration curves for InSb and GaSb are shown. The Kamenetskaya equations were used for the theoretical points and a qualitative correlation was obtained.

11,254 ON BINARY SYSTEMS WITH GERMANIUM: Ge-Al, Ge-Sn, Ge-Si [in German] by H. Stoehr and W. Klemm; Z. Anorg. Chem., Vol. 241, No. 4, pp. 305-424, 1939

A systematic study of the compounds formed by Ge with Al, Sn, and Si is reported. The investigation of systems containing semi-metals leads to an explanation of the more exact affinity relations. Al and Ge, as well as Zn and Ge, form eutectic systems. The solubility in the solid state can be estimated by x-ray methods. Ge and Si form a continuous series of mixed crystals. The equilibrium is established very slowly and the change in lattice constants is linear. The behavior of Al in relation to the elements of the 4th group and the mutual behavior of the 4th group elements are discussed. It is shown that the solubility is lowered if two metals show significant differences in their metallic characteristics.

11,255 ON THE SYSTEMS $\text{In}_2\text{Se}_3\text{-InP}$, $\text{In}_2\text{Se}_3\text{-InAs}$, $\text{In}_2\text{Te}_3\text{-InAs}$, InSe-InAs AND InTe-InAs [in German] by H. Hahn and O. Thiele (Kiel U.); Z. Anorg. Chem., Vol. 303, pp. 147-154, 1960

The results of an investigation of the systems $\text{In}_2\text{Se}_3\text{-InP}$, $\text{In}_2\text{Se}_3\text{-InAs}$, $\text{In}_2\text{Te}_3\text{-InAs}$, InSe-InAs and InTe-InAs by x-ray analysis are given. Mixed crystal phases of the zincblende type were found in all the systems. The system $\text{In}_2\text{Te}_3\text{-InAs}$ appears as a continuous series of mixed crystals. In the other systems the range of homogeneity of the mixed crystal phase starting with pure InP or InAs extends only a little beyond the mole ratio 1:1. The easy formation of mixed crystals of the zincblende type is explained by the tendency of the indium to form tetrahedral coordination in compounds with nonmetals.

11,256 AN INVESTIGATION OF THE SECTION $\text{InAs-In}_2\text{Se}_3\text{-Se}$ IN THE SYSTEM In-As-Se by S. I. Radautsan (USSR Acad. Sci.); Russ. J. Inorg. Chem., Vol. 4, pp. 510-511, 1959

The formation and temperature-phase testing of fifteen different alloys of In-As-Se are reported. 5-7 gm powdered mixtures were heated in an As atmosphere. Some specimens were annealed at 600°C for 1100 hrs. Phase change vs temperature were recorded and microhardness was determined. An $\text{H}_2\text{O}_2 + \text{NH}_4\text{OH}$ etch revealed the microstructure. Use of this information in homogenization and zone melting techniques is suggested.

11,257 STRUCTURE OF TERNARY SYSTEMS OF METALS OF THE THIRD AND FIFTH GROUP OF THE PERIODIC SYSTEM [in German] by W. Koester and B. Toma (Max Planck Inst. Metall.); Z. Metallkde., Vol. 46, No. 4, pp. 293-297, 1955

The structure of the ternary systems Al-Ga-Sb, Al-In-Sb, Ga-In-Sb, and AlSb-GaSb-InSb is discussed. The sections AlSb-GaSb, AlSb-InSb, and GaSb-InSb are quasibinary. The melting plane of the ternaries is actually controlled by the primary crystallization of the compound with the highest melting point.

The crystallization of the remaining phases is forced back to a narrow region along the boundary system. The ternary eutectics are degenerated and the ternary bonds do not appear.

Structure of Ternary Alloys - See 11,374 and 11,375

11,258 A NEW SEMICONDUCTING COMPOUND IN THE In-Sb-Te SYSTEM by N. A. Goryunova, S. I. Radautsan, and G. A. Kiosse (USSR Acad. Sci.); Soviet Phys.-Solid State, Vol. 1, pp. 1702-1704, June 1960

An investigation of the InSb-InTe section of the ternary system In-Sb-Te is reported. Five alloys have been prepared and studied by means of x-ray and microhardness techniques. In the x-ray diffraction patterns, the structures of InSb and InTe could be easily seen. In the 3 InSb·InTe and InSb·InTe alloys, the ZnS lines were accompanied by lines of a second phase with a NaCl-type structure, whose intensities increased on approaching the InSb·InTe alloy. In the InSb·3InTe alloy, only lines representing the NaCl structure were observed. Evidence of the existence of the compound In_4SbTe_3 with the NaCl structure and a lattice constant $a = 6.12 \pm 0.003 \text{ \AA}$ was found. A preliminary study of the electrical properties has indicated that In_4SbTe_3 is a semiconductor.

11,259 METASTABLE ELECTRON COMPOUND IN Ag-Ge ALLOYS by P. Duwez, R. H. Willens, and W. Klement, Jr. (Calif. Inst. Tech.); J. Appl. Phys., Vol. 31, p. 1137(L), 1960

A metastable Ag-Ge alloy containing 25.7 atomic per cent Ge is described. The alloy was formed by rapid quenching from the eutectic Ag-Ge alloy with 25.9 atomic per cent Ge. The alloy was found to have a hexagonal close packed structure with $a = 2.987$, $c = 4.716$ and $a/c = 1.628$. X-ray diffraction showed traces of Ge diamond cubic structure. Electron concentration is thought to be 7/4 electrons/atom.

11,260 HETEROGENEITIES IN SOLID SOLUTIONS by A. Guinier (U. Paris); Solid State Phys., Academic Press, 1959, Vol. 9, pp. 293-398

The structure of metallic solid solutions, which to a first approximation are homogeneous, disordered substitutional solutions, is discussed. Only the case in which no long-range order exists is considered. The principles of studying lattice faults by x-ray scattering are presented and experimental techniques for the application of these principles are briefly described.

11,261 ON THE ISOMORPHISM OF COMPOSITIONS WITH COVALENT BOND [in Russian] by N. A. Goryunova and N. A. Federova; Doklady AN SSSR, Vol. 90, No. 6, pp. 1039-1041, 1953

Experimental data on the isomorphism of some binary compositions with various degrees of "bond covalency" are given. X-ray, microscopic and seed crystal (trigger) methods have been employed for the estimation of the presence of solid solutions or two phases. The least covalent of the investigated compositions, CdTe and ZnTe, CdTe and HgTe, form solid solutions. The more covalent compositions (InSb and InAs) have the same differences in lattice parameters as CdTe and ZnTe but do not form any solid solutions. The solid solutions $m\text{CdTe} \cdot n\text{ZnTe}$, $m\text{CdTe} \cdot n\text{HgTe}$ are isomorphic with gray tin up to a certain limit. For both systems this limit appears at the same concentrations, leading to a conclusion that the

similarity of the bonds is of more importance than the similarity in lattice parameters. It can be assumed, that the more covalent the bond of the composition, the more stringent the conditions of isomorphism.

11,262 X-RAY INVESTIGATION OF ISOMORPHISM OF SOME COMPOSITIONS OF GALLIUM AND ZINC [in Russian] by N. A. Goryunova, V. A. Korovich, Va. A. Frank-Kamenetskii (U. Leningrad); Doklady AN SSSR, Vol. 103, Nov. 4, pp. 659-662, 1955

The possibility of isomorphic substitutions in compositions of Se and Te with Ga and Zn is discussed. Binary compositions have been synthesized by the alloying of stoichiometric quantities of materials. It is estimated that in the system Ga_2Se_3 -ZnSe a continuous series of solid solutions is formed corresponding to a more ionic type of bond than that of Ga_2Te_3 -ZnTe, which forms only a limited series of solid solutions. The results of an x-ray analysis are discussed. A table of crystallographic data is given as well as x-ray pictures. The influence of ionic and covalent types of bonds is compared with the observations and data given by other investigators. The appearance of gallium is explained on the basis of the isomorphism of compositions of Se and Te.

11,263 ON THE PROBLEM OF ISOMORPHISM OF TYPE $A^{III}B^V$ COMPOUNDS [in Russian] by N. A. Goryunova and N. N. Fedorova (USSR Acad. Sci.); Zhum. Tek. Fiz., Vol. 25, No. 7, pp. 1339-1341, 1955

The results of experimental investigations of the solid solutions GaAs-GaSb, InAs-InSb, GaAs-InAs, GaSb-InSb in wide concentration ranges are reported. The analysis was carried out by the x-ray powder method. The alloys InAs-InSb and GaAs-GaSb did not show any solid solubility. Solubility of the alloys GaSb-InSb and GaAs-InAs depends on the heating time. The system GaSb-InSb, after 100 hrs of annealing, showed narrow lines on the x-ray picture. The system GaAs-InAs did not show complete homogeneity after the same period of annealing. Isomorphism depends on the type of chemical binding. Compounds with "more" ionic binding form solutions easier than compounds with "more" covalent binding. Alloys with equal cations (e.g., GaAs, GaSb) make easier solid solutions than alloys with equal anions (GaSb-InSb). The maximum electron density in crystals is shifted toward anions and this is presumably the reason for weaker anion isomorphism.

11,264 ISOMORPHISM OF TYPE $A^{III}B^V$ COMPOUNDS [in German] by W. Koester and W. Ulrich (Max Planck Inst. Metall.); Z. Metallkde., Vol. 49, No. 7, pp. 365-367, 1958

The formation of mixed crystals of GaSb-InSb, AlSb-GaSb, AlSb-InSb and InP-InAs is discussed. The $A^{III}B^V$ compounds with zincblende structure mostly form solid solutions in thermal equilibrium. Some alloys like InP-InAs crystallize immediately in homogeneous solutions; others, e.g., GaSb-InSb, show strong segregation. Homogenization of these alloys is a very slow process. Some ternaries determined earlier have to be corrected for this reason.

Solid Solutions of $A^{III}B^V$ Compounds - See 11,263 and 11,264

11,265 SOLID SOLUTION IN THE GaAs-InAs SYSTEM by J. C. Woolley and B. A. Smith (U. Nottingham); Proc. Phys.

Soc., Vol. 70B, pp. 153-154 (L), Jan. 1957

Observation of solid solution throughout the entire range of composition in the GaAs-InAs system is reported. Information on the production and annealing of the alloys and measurement of x-ray powder photographs are given. All alloys had the zincblende structure and Vegard's law was shown to be satisfied.

11,266 THE ARSENOSELENIDES OF GALLIUM by N. A. Goryunova and V. S. Grigor'eva (USSR Acad. Sci.); Soviet Phys.-Tech. Phys., Vol. 1, pp. 2094-2098, 1956

An investigation of seven pseudo binary compositions of GaAs and GaSe is reported. X-ray diffraction was used to establish lattice constants and to analyze the phases (nine pictures are included). In addition microstructure was examined after polishing and etching, specific gravity was measured, and a thermal analysis was made. It is concluded that this system gives a continuous series of substitutional solid solutions and that the interatomic bonds of these two Ga compounds must be quite similar.

11,267 SOLID SOLUTIONS IN THE Ga_2Te_3 - In_2Te_3 SYSTEM by V. S. Grigor'eva (USSR Acad. Sci.); Soviet Phys.-Tech. Phys., Vol. 3, p. 1539, 1958

An investigation of a series of seven pseudo-binary alloys of In and Ga tellurides by x-ray diffraction is described. The alloys were formed by melting stoichiometric proportions in vacuum. Specific gravities of all alloys were measured, and an x-ray powder camera was used to obtain information on the isomorphic miscibility. Nine of these pictures are shown. It is concluded that this system gives a continuous series of substitutional solid solutions.

11,268 ADDITIONAL EVIDENCE CONCERNING SOLID SOLUTIONS IN THE AlSb-GaSb SYSTEM by I. I. Brudiyan (Ped Inst., Tiraspol); Soviet Phys.-Solid State, Vol. 1, pp. 1246-1252, Mar. 1960

An investigation of solid solutions in the AlSb-GaSb system is reported. Nonequilibrium alloys were obtained by synthesis of the component elements. Equilibrium solid solutions were then obtained by zone refining the nonequilibrium alloys. A high degree of homogeneity was obtained by using a slow rate of zone travel. It was found that the microhardness of the alloys increases after zone refining and that the microhardness passes through a maximum at the composition AlSb-GaSb. X-ray analysis indicates that Vegard's law is satisfied in the AlSb-GaSb system. From optical absorption measurement, the band gap was found to vary from 0.93 ev in AlSb-4GaSb to 1.47 ev in 4AlSb GaSb.

11,269 STUDIES OF ALLOYS IN THE SYSTEM AlSb- Al_2Te_3 by M. S. Mirgalovskaya and E. V. Skudnova (USSR Acad. Sci.); Russ. J. Inorg. Chem., Vol. 4, pp. 506-509, May 1959

An investigation of the solid solutions in the system AlSb- Al_2Te_3 is reported. The solidus was determined by the temperature dependence of electrical conductivity and the solid solubility limit of Al_2Te_3 in AlSb was determined by microstructural and x-ray analyses. X-ray examination showed that the solution of Al_2Te_3 in AlSb is an example of hetero-valent substitution. The temperature variation of electrical conductivity reverse voltages and the thermal EMF of the solid solution have also been studied.

11,270 SOLID SOLUTIONS IN THE SYSTEM $\text{InAs-In}_2\text{Te}_3$ by N. A. Goryunova and S. I. Radautsan (USSR Acad. Sci.); *Soviet Phys.-Doklady*, Vol. 3, pp. 854-855, 1958

Investigations of solid solutions of varying proportions of InAs and In_2Te_3 are reported. Precise amounts of the materials were sealed in ampules in an argon atmosphere and subjected to controlled heating to 1000°C . After a one-hour soak, the temperature was lowered at 60° to 100°C per hour. The lattice constant on the resulting specimens was found to vary linearly with concentration ratio. Etching uncovered a dendritic structure in most of the specimens, particularly at the edges.

11,271 SOLID SOLUBILITY OF In_2Se_3 IN SOME COMPOUNDS OF ZINC BLENDE STRUCTURE by J. C. Woolley (U. Nottingham) and P. N. Keating (AEI Ltd.); *J. Less Common Metals*, Vol. 3, pp. 194-201, June 1961

A study of the ranges of solid solubility of In_2Se_3 in the zinc-blende type compounds InAs , InSb , In_2Te_3 and Ga_2Se_3 by x-ray methods is reported. The solubility ranges are found to be appreciable in the case of InAs , In_2Te_3 and Ga_2Se_3 and only in the case of InSb is the range limited to a few mole per cent. It is found that in most cases prolonged annealing is required before equilibrium is attained, particularly for the AlIIBV compounds, InAs and InSb . Ordering effects have been observed in the $\text{InAs-In}_2\text{Se}_3$ system and in the $\text{In}_2\text{Te}_3\text{-In}_2\text{Se}_3$ systems. In the $\text{Ga}_2\text{Se}_3\text{-In}_2\text{Se}_3$ system, the blurring of x-ray powder lines is attributed to stacking faults occurring in the alloys and in Ga_2Se_3 itself.

11,272 FORMATION OF SOLID SOLUTIONS AND MAGNETIC SUSCEPTIBILITY OF THE SYSTEMS HgTe-HgSe , $\text{HgTe-}\beta\text{HgS}$, $\beta\text{HgS-}\beta\text{HgS}$ [in Russian] by E. I. Nikolskaya and A. R. Regel' (USSR Acad. Sci.); *Zhurn. Tek. Fiz.*, Vol. 24, No. 8, pp. 1347-1351, 1955

The physical properties and crystal structure of the compounds HgTe , HgSe , βHgS , HgS and αHgS are discussed. The preparation of these alloys and their solid solutions and observations of changes in their external appearance and magnetic properties during the process of annealing are described. Curves of magnetic susceptibility versus component ratio for the three systems are given.

11,273 FERRIMAGNETIC GARNETS by S. Geller (Bell Labs.); U.S. Pat. 3,006,855, Issued Oct. 31, 1961

Solid solutions of yttrium iron garnet ($\text{Y}_3\text{Fe}_5\text{O}_{12}$) and other rare earth iron garnets with the garnet $\text{M}_3\text{Fe}_2\text{Sn}_3\text{O}_{12}$, where M is Ca, Ba, or Sr, are discussed. The resulting garnet exhibits, within a certain composition range, a saturation magnetic moment which is larger than that of the rare earth iron garnet. A solid solution of $\text{Y}_3\text{Fe}_5\text{O}_{12}$ and $\text{Ca}_3\text{Fe}_2\text{Sn}_3\text{O}_{12}$, for example, exhibits a magnetic moment larger than that of $\text{Y}_3\text{Fe}_5\text{O}_{12}$ up to solid solutions containing 33 mole per cent $\text{Ca}_3\text{Fe}_2\text{Sn}_3\text{O}_{12}$. A theoretical explanation for this effect is presented and the preparation of specific garnets is described.

Solid Solutions of YIG and Other Garnets - See 11,319

11,274 MELTING PHENOMENA WITH SILICON by C. H. L. Goodman (GE); *Solid-State Electronics*, Vol. 3, pp. 72-73 (L), July 1961

The observation that freshly prepared Si surfaces melt at temperatures several degrees lower than the melting point of pure Si is discussed. Blocks of freshly etched Si were melted in a steep temperature gradient under dry hydrogen. On the interface between melted and unmelted regions, striae, which appear to be the tracks of small globules of molten material on unmelted Si, were observed. It is suggested that impurities left on the surface depress the freezing point of Si to form a molten region and that this region migrates up the temperature gradient by the gradient zone-melting mechanism postulated by Pfann. Electron diffraction examination and high temperature observation yielded further results of interest.

11,275 RATE OF CONTACT MELTING OF METALS [in Russian] by A. V. Viatkina (Tomsk Polytech. Inst.); *Izv. VUZ, Fizika*, No. 3, 1961, pp. 56-61

Measurements of the rate of contact melting for binary, ternary, tertiary, and five-component systems are discussed. The significance of aging time for binary, ternary, and tertiary eutectics has also been studied. Values of the activation energy of the contact melting are presented. Contact melting at temperatures exceeding the contact melting temperature is related to the solubility.

11,276 PHASE TRANSITION OF In_2Se_3 by H. Mitazawa and S. Sugaike (Tokyo-Shibaura Elect.); *J. Phys. Soc., Japan*, Vol. 12, p. 312, 1957

A study of the phase transition of In_2Se_3 is reported. The hexagonal lattice structure of In_2Se_3 single crystals grown by means of the double furnace techniques has been confirmed by x-ray examination. At nearly 200°C In_2Se_3 has a remarkable phase transition which may be first order. The electrical conductivity along the (0001) plane decreases abruptly and the Hall constant increases suddenly at the transition temperature T_c . Volume contraction also occurs at the transition. Anisotropy in thermal expansion and current-voltage characteristics is observed.

Order-Disorder Transition in the $\text{AgSbSe}_2\text{-AgSbTe}_2\text{-AgBiSe}_2\text{-AgBiTe}_2$ System - See 11,251

Homogenization of In-As-Se Alloys - See 11,256

Microstructure of Semiconducting Alloys - See 11,474

CRYSTAL STRUCTURE

CRYSTAL LATTICES

11,277 LATTICE PARAMETER DETERMINATIONS WITH AN X-RAY SPECTROGONIOMETER BY THE DEBYE-SCHERRER METHOD AND THE EFFECT OF SPECIMEN CONDITION by H. E. Otte (Rias); *J. Appl. Phys.*, Vol. 32, pp. 1536-1546, Aug. 1961

The use of the Debye-Scherrer method on an x-ray spectrogoniometer to determine lattice parameters is described. Complete profiles of diffraction lines have been recorded and the center

CRYSTAL LATTICES (Cont'd)

of gravity has been determined with an accuracy of $\pm 0.005^\circ 2\theta$. The lattice constant was calculated from each reflection and plotted against the Nelson-Riley function. The lattice constant of pure Se was found to be unaffected by the condition in which it was examined. However, lattice constants of single-phase alloys are in general quite sensitive to their state of preparation. The influence of short-range ordering, stacking faults, solute clustering, quenching stresses, etc. is discussed.

11,278 A MATHEMATICAL TECHNIQUE FOR THE PRECISION DETERMINATION OF LATTICE PARAMETERS by R. E. Vogel (Kaman) and C. P. Kempter (U. California); *Acta Cryst.*, Vol. 14, pp. 1130-1134, Nov. 1961

A computer code developed for the precision determination of crystal lattice parameters is discussed. The code uses the Hess method as a basis, with the following modifications: (1) No approximations are made in the solution of the observation equation and (2) The method is extended to the hexagonal and orthorhombic crystal systems and to additional extrapolation functions. In the majority of the determinations, with randomly selected materials, the Hess approximation gave results comparable with the exact technique; however, because of certain restrictions, the exact technique is recommended.

11,279 ON THE THEORY OF THE STRUCTURE OF BINARY WURTZITE-TYPE CRYSTALS [in Russian] by V. A. Zhdanov and L. A. Brysneva (SFTI, Tomsk U.); *Izv. VUZ, Fizika*, No. 3, pp. 95-102, 1961

Analysis of the influence of the character of the binding force on the deviation of lattices of wurtzite type from the ideal case of close packing of spheres is presented. It is shown that the bonds approximated by the Born formula for ionic crystals lead to deviations which agree with experimental results. A qualitative deduction is made on the possible influence of valence bonds.

Lattice Constants of:

Ge-Si Alloys - See 11,337

InP - See 11,292

the Ternary System $Mg_2Ge_ySn_{1-y}$ - See 11,377

Cubic Phase Solid Solutions in the $AgSbSe_2$ - $AgSbTe_2$ - $AgBiSe_2$ - $AgBiTe_2$ System - See 11,251

CRYSTAL IMPERFECTIONS

11,280 X-RAY DIFFRACTION BY FACE CENTERED CUBIC CRYSTALS WITH DEFORMATION FAULTS by M. S. Paterson (U. Chicago); *J. Appl. Phys.*, Vol. 23, p. 805, 1958

A rigorous theoretical treatment of x-ray diffraction by crystals with deformation caused faults is given. Diffraction angles and corresponding line broadening are calculated for a face centered cubic crystal with a fault in the (111) plane resulting from plastic deformation (as opposed to a growth fault). The results can be applied to polycrystalline samples.

X-Ray Scattering Method for Studying Lattice-Faults - See 11,260

11,281 SILICON DIVACANCY AND ITS DIRECT PRODUCTION BY ELECTRON IRRADIATION by J. W. Corbett and

G. D. Watkins (GE); *Phys. Rev. Lett.*, Vol. 7, pp. 314-316 (L), Oct. 15, 1961

The divacancy, an intrinsic defect which is stable at room temperature and which is produced by room temperature electron irradiation of Si, is discussed. The divacancy is produced directly in a high energy electron irradiation. The high anisotropy of the divacancy production rate indicates that the divacancy is produced by the following process: A high energy electron collides with the nucleus of an atom and imparts a recoil energy to the atom, causing it to be displaced into the lattice as an interstitial. The initial recoil atom retains enough energy so that it also becomes an interstitial. The divacancy production rate is ~ 5 per cent of the vacancy production rate for a 1.5 Mev irradiation and plays an important part in room temperature radiation damage processes.

Effects of Composition Upon Vacancy Concentrations of KCl-KBr - See 11,366

11,282 INTERSTITIAL MOTION NEAR $40^\circ K$ IN COPPER by A. V. Granato (U. Illinois) and T. G. Nilan (U.S. Steel); *Bull. Am. Phys. Soc.*, Vol. 6, Ser. II, p. 419 (A), Nov. 24, 1961

An analysis of annealing kinetics in Cu near $40^\circ K$ for recombination of interstitials with vacancies was presented. The analysis shows that "close pair" annihilation should follow first-order kinetics, interstitial-vacancy recombination through the motion of the interstitial in three dimensions should follow second-order kinetics, but recombination resulting from one-dimensional (crowding) motion of the interstitial should follow third-order kinetics. The rate at which annealing occurs has a maximum, whose location depends upon the activation energy, number of jumps to annihilation, and warming rate. The shift of the position of the maximum with concentration of defects depends upon the annealing kinetics. It is greatest for third-order, intermediate for second-order, and zero for first-order kinetics. A comparison of the calculated peak shifts with the electron radiation experiments of Corbett, Smith, and Walker shows that the data are consistent with three-dimensional motion of the interstitial but inconsistent with one-dimensional motion. The argument does not depend on the magnitude of the number of jumps made by the interstitial.

11,283 RELAXATION AND ACTIVATION ENERGIES FOR AN INTERSTITIAL NEUTRAL DEFECT IN AN ALKALI HALIDE LATTICE by R. D. Hatcher (New York U.) and G. J. Dienes (Brookhaven Natl. Lab.); *Phys. Rev.*, Vol. 124, pp. 726-735, Nov. 1, 1961

A method for calculating the relaxation energy for an interstitial neutral defect in an alkali halide lattice is discussed. The method involves expanding the electrostatic polarization and dipole-dipole energy contributions to second order in terms of the displacements of the ions from their regular positions. The repulsive energy contributions involving the defect atom are treated exactly, whereas the repulsive contributions involving the regular ions themselves are also expanded to second order. This method has been applied to the case of an interstitial chlorine atom in NaCl for positions where the defect atom is at the center of a cube of ions and at the center of a square of ions; the difference when related to the same standard configuration gives an activation energy of approximately 0.5 eV for the migration of a neutral interstitial chlorine atom in NaCl.

11,284 LATTICE IMPERFECTIONS IN METALS, SEMICONDUCTORS AND IONIC CRYSTALS by H. G. van Bueren;

Philips Tech. Rev., Vol. 22, pp. 362-373, 1960/61

Differences in the behavior of lattice imperfections in various materials, particularly the manner in which the imperfections are formed and their influence on the electrical and mechanical properties of the substance concerned, are discussed. The formation of lattice imperfections may be accompanied by electrostatic effects. As a result, dislocations in non-metals generally possess a charge and are surrounded by a space-charge region which affects the mobility and concentration of charge-carriers. It is shown, with reference to experiments, that the movement of dislocations in almost perfect polar and covalent crystals follows virtually the same laws, and it is concluded that similar laws must also in principle apply to metals. The distribution of dislocation sources and the significance of the surface in this respect is mentioned.

11,285 CHARGED DISLOCATIONS IN IONIC CRYSTALS by F. Rueda and W. Dekeyser (Lab. Kinstallografic, Belgium); *J. Appl. Phys.*, Vol. 32, p. 1799(L), Sept. 1961

Observations of charged dislocations in certain ionic crystals are reported. Chemically polished pure and doped rocksalt, and LiF and MgO single-crystals were indented with a Leitz microhardness tester and the charge of the dislocations was recorded, one of the electrodes being evaporated into the crystals. The dislocations were found to be negatively charged in rocksalt and LiF crystals, and positively charged in MgO. No difference in magnitude or sign was found if the specimens were afterwards polished or between annealed and quenched specimens. Variations of the measuring apparatus allowed a continuation of the experiment. Doped rocksalt exhibited different behavior depending on the doping element.

Dislocation Etch Pits in PbTe - See 11,324

Fe and In Dislocations in InSb - See 11,325

Control of Alloying and Diffusion by Dislocation Densities - See 11,488

11,286 GERMANIUM DOUBLE CRYSTALS IN GRAIN BOUNDARY PHOTOCELLS [in German] by H. F. Mataré (Tekade Semicon. Lab.); *Elektron. Rundschau*, Vol. 15, No. 2, pp. 57-60, 1961

The mechanical and chemical structures of the grain boundary, especially the potential field produced by free bonds and the resulting change of the electronic band distance, are considered. The stabilizing grain-boundary energy is discussed and the model of the central-angle grain boundary is described. The effect of impurities is considered, especially in the region of the central angle-grain boundaries where the effect appears to be rather insignificant.

Properties of the Interface in Ge Bicrystals - See 11,429

Winning in Noble Metal Films - See 11,295

11,287 THE NATURE OF THE MOSAIC STRUCTURE OF GERMANIUM AND SILICON SINGLE CRYSTALS by O. V. Bogorodskii, Ya. S. Umanskii, and S. Sh. Shil'shtein (Stalin Moscow Steel Inst.); *Proc. Acad. Sci. USSR, Phys. Chem. Section*, Vol. 134, pp. 803-805, Sept.-Oct. 1960

The mosaic structure of Ge and Si single crystals is discussed. Rocking curves were measured in Ge crystals containing an irregular distribution of impurities. A mosaic structure was

found in crystals with dislocation densities ranging from $10^2/\text{cm}^2$ to $10^6/\text{cm}^2$. The angles of misfit and the block sizes were found to change very little over this range of dislocation density. The observation of mosaic structure in crystals containing on the order of 10^2 dislocations per cm^2 does not agree with the Burgers model, nor does the slight change in angles of misfit and block size. In Si crystals containing dislocation densities on the order of 10^2 to $10^3/\text{cm}^2$, the Si block size was found to be much smaller than in Ge. This observation also does not fit the Burgers model, since the size of the Si and Ge lattices is almost identical. The experimental data indicate that the boundaries between the blocks are not due to low angle boundaries.

IMPURITIES

11,288 RESEARCH INVESTIGATIONS OF SEMICONDUCTOR IMPURITIES by C. E. Harvey (Harvey Assoc.); *U.S. Gov. Res. Rep.*, Vol. 36, p. 39(A), July 5, 1961 AD 255 825

A general quantitative or semi-quantitative analytical system for non-metallic elements using spectrochemical methods is described. The method permits the simultaneous determination of Cl, Br, I, S, Se, and P in a single operation. Included are spectrum line sensitivities for the above elements, with detectability limits shown for all lines of these elements in the region 3040A - 4830A. This wave length range was established as the most valuable region obtainable with the spectrograph used and the discharge conditions employed. The investigation utilized a widely used source unit producing a 20,000 v unidirectional discharge. An extensive investigation was made to determine optimum constants for pressure, inductance and primary voltage.

11,289 DECONTAMINATION PROCESS by J. E. McNamara (Motorola); *U.S. Pat. 3,007,816*, Issued Nov. 7, 1961

A technique for removing Cu, Fe, Ni, or their oxides from intrinsic or very high resistivity n-type Si or Ge during the diffusion of an n-type impurity into the semiconductor is described. The semiconductor is heated in the diffusion chamber while in contact with an oxide of a metal of group 4b, 5b, or 6b of the periodic table, such as Mo, W, Ta, or Ti. The getters remove the impurities from both the surface and the interior of the wafer. Gettering is achieved by the formation of stable compounds such as copper molybdate and copper tungstate. The technique is described particularly in connection with the preparation of diffused base transistors.

11,290 METHOD FOR DIFFUSING ACTIVE IMPURITIES INTO SEMICONDUCTOR MATERIALS by C. A. Levi (Pacific Semiconductor); *U.S. Pat. 3,003,900*, Issued Oct. 10, 1961

A technique for the simultaneous diffusion of a conductivity type-determining impurity into Ge or Si and the removal of undesired fast-diffusing impurities such as Cu, Au, Ni and Fe from the semiconductor and the diffusion system is described. The semiconductor is heated in a sealed tube containing the semiconductor and an impurity source in one compartment, and a getter which is molten at the diffusion temperature in another compartment. The getter has a low vapor pressure and a high solubility for the fast-diffusing impurity. The tube is filled with the vapor of a halide such as CCl_4 which decomposes at the diffusion temperature. The physics of the process is discussed. The technique can also be used solely for the removal of a fast-diffusing impurity, i.e., without the simultaneous diffusion of a type-determining impurity.

IMPURITIES (Cont'd)

11,291 OPEN TUBE DIFFUSION OF PHOSPHORUS IN SILICON by W. J. Greig and J. C. Sarace (RCA); J. Electrochem. Soc., Vol. 108, p. 175C (A), Aug. 1961

Experimental data for phosphorus diffusion in Si employing an open tube carrier gas system are presented. Using P_2O_5 as the diffusant source, the surface concentration is calculated in terms of the system parameters, namely, effects of source age, source temperature, Si temperature, carrier gas, and carrier gas flow rate. Surface concentrations are calculated from sheet resistance and junction penetration measurements using the curves of Blackenstoss. Data obtained from an evaluation of the diffusion coefficient calculated assuming a complementary error function distribution are given, showing a dependence on the surface concentration and wafer surface condition. Anomalous results obtained from effect of source temperature on surface concentration and the diffusion coefficient as a function of surface concentration also are discussed.

Thermoeffusion of Impurities in Fluids - See 11,470

Precipitation of $MnCl_2$ in NaCl - See 11,469

NON-STOICHIOMETRY

11,292 THE PROPERTIES OF STOICHIOMETRIC AND NON-STOICHIOMETRIC INDIUM PHOSPHIDE COMPOUNDS by N. A. Goryunova, N. N. Fedorova, and V. I. Sokolova (Phys.-Tech. Inst., Leningrad); Soviet Phys.-Tech. Phys., Vol. 3, pp. 1542-1545, Aug. 1958

X-ray diffraction measurements performed at $25 \pm 0.5^\circ C$ per cent on stoichiometric InP and on InP containing an excess of either In or P are discussed. The preparation of the samples is described. The In contained only insignificant traces of copper; the phosphorus contained a few thousandths per cent of Cu, Al, Fe, Mg, and Si. Microstructure and microhardness investigations carried out to determine the presence of excess In or P are discussed. In each sample investigated, the zincblende type structure was found. The lines of metallic indium were also observed in InP containing excess In. It was found that the lattice constant $a = 5.8693 \text{ \AA}$ and that within the limits of accuracy of $\pm 0.0006 \text{ \AA}$ it remains constant in the presence of an excess of either component.

Creation of Oxygen Non-Stoichiometry in $BaTiO_3$ - See 11,432

STRUCTURE

Structure of Melted-Unmelted Regions on Si Surfaces - See 11,274

STRUCTURE OF SPECIAL CRYSTAL FORMS

11,293 A METHOD FOR THE STUDY OF NUCLEATION OF THIN FILMS by A. E. Cahill (GE); J. Electrochem. Soc., Vol. 108, p. 174C (A), Aug. 1961

A technique for determining the relative proportion of Au and of nickel-iron constituting the surface of a thin film is presented. When very thin layers of nickel-iron have been elec-

troplated on a gold substrate, it is possible by this means to determine to what extent the nickel-iron is continuous. When the nickel-iron deposits in islands, the hydrogen overvoltage indicates that the solution is in contact with both gold and nickel-iron.

11,294 TEXTURAL PROPERTIES OF GERMANIUM FILMS by J. E. Davey (U.S. Naval Res. Lab.); J. Appl. Phys., Vol. 32, pp. 877-880, May 1961

Detailed investigations of the textural properties of thin Ge films vacuum evaporated onto hot fused quartz substrates over the temperature range from ambient to $650^\circ C$ are reported. The strongest texture characteristic of these films is the [110], which is obtained at substrate temperatures as low as $175^\circ C$ and prevails up to about $350^\circ C$. For temperatures between 350° and $575^\circ C$, competition for growth occurs and the texture varies principally between being powder, [110] and [111]. Above $575^\circ C$ the [111] texture becomes dominant.

11,295 EPITAXY AND TWINNING IN FOILS OF SOME NOBLE METALS CONDENSED UPON LITHIUM FLUORIDE AND MICA by M. J. Hall and M. W. Thompson (Atom. Energy Res. Estab.); Brit. J. Appl. Phys., Vol. 12, pp. 495-498, Sept. 1961

Foils of Cu, Ag, Pd and Au up to $2.5 \times 10^{-3} \text{ cm}$ in thickness evaporated on LiF and mica crystals are discussed. Epitaxial growth was observed within fixed temperature ranges for each substrate-metal combination. X-ray diffraction of the foils produced sharp patterns of spots which indicated a principal orientation of crystallites in direct alignment with the substrate crystal, together with twins whose presence was confirmed by metallography. The observations are discussed in terms of a nucleation and growth model.

STRUCTURE OF SPECIFIC MATERIALS

11,296 ON THE CRYSTAL STRUCTURE OF In_2S_3 AND In_2Te_3 [in German] by H. Hahn and W. Klinger (U. Heidelberg); Z. Anorg. Chem., Vol. 260, pp. 97-109 (C), 1949

An x-ray analysis of the crystal forms of In_2S_3 and In_2Te_3 is discussed. The low temperature configuration (α) of In_2S_3 has a fcc lattice, $a = 3.36^\circ \text{ \AA}$, with a cubic closest packed structure of the sulphur atoms. The indium atoms are statistically distributed such that about $2/3$ are in the octahedral interstices and $1/3$ in the tetrahedral interstices. Some very weak lines indicate a superstructure with a double lattice constant determined by the deformation of the sulphur positions. This modification above $300^\circ C$ changes into the high temperature form (β). An arrangement of the metal atoms and the formation of a spinel-like lattice, $a = 10.72^\circ \text{ \AA}$, takes place. $\beta\text{-}In_2S_3$ is an isotype of $\gamma\text{-}Al_2O_3$. The In_2Te_3 has a zincblende structure $a = 6.14^\circ \text{ \AA}$.

11,297 ON THE STRUCTURE OF GALLIUM CHALCOGENIDES [in German] by H. Hahn (U. Kiel); Angew. Chem., Vol. 64, No. 7, p. 203 (C), 1952

Examinations of the superstructure lines in the components of Ga_2S_3 are discussed. By the annealing of the components a rearrangement takes place which leads to the formation of a new Wurtzite-like lattice. Complete explanation of the crystal structure of the annealed Ga_2S_3 is possible only by analysis of a single crystal. Superstructure lines can also be

observed in the zincblende lattice alloys Ga_2Se_3 , Ga_2Te_3 , and In_2Te_3 after a longer period of annealing, which indicates the proper distribution of metal atoms.

Crystal Structure of:

MnHg - See 11,411

LaCrO₃ - See 11,412

the HgSe-HgTe System - See 11,357

In-Sb-Te Compounds - See 11,258

Structure of SiO₂ Glass - See 11,475

CRYSTAL GROWTH

SEMICONDUCTOR CRYSTALS

11,298 THE USE OF R-F HEATING IN GROWING CRYSTALS BY THE CZOCHRALSKI TECHNIQUE by W. A. Emerson (Westinghouse); *Semicon. Prod.*, Vol. 4, pp. 25-31, Oct. 1961

The problems encountered in the use of induction heating in the Czochralski technique for growing crystals are discussed. A non-conducting heat shield is used to decrease heat loss by radiation, and excessive heating under the coil turns is minimized by loose coupling. Temperature taper is obtained by increasing the longitudinal spacing of the coil turns at one end, while extension of the coil beyond the work maintains a constant flux field in the work. Temperature control is achieved by a continuous electronic control using magnetic amplifiers and saturable reactors. A comparison of the induction heater and the resistance furnace is presented.

11,299 THE SHAPE OF METAL-CRYSTAL INTERFACES DURING FLOAT ZONING OF SILICON by J. H. Braun and R. A. Pellin (duPont); *J. Electrochem. Soc.*, Vol. 108, pp. 969-974, Oct. 1961

The thermal environment of the growth interface of a Si crystal during float zoning is described. Depending on operating conditions, the interface between the melt and the growing crystal can be convex, nearly flat, or concave. The shape of the interface was made visible by slot doping of n-type Si with excess B dope to give a p-n junction between n-type crystal and p-type melt. This junction, outlining an interface, was decorated with a staining etchant.

11,300 GROWTH OF LITHIUM FLUORIDE WHISKERS by E. W. Nadgornyi (Phys.-Tech. Inst., Leningrad); *Soviet Phys.-Solid State*, Vol. 3, p. 694, Sept. 1961

A method of growing LiF whiskers is described. The main difficulty of growing LiF through a partition is its low solubility in water. To avoid this, crystallization is carried out using a two-component solution. Solutions of LiCl and KF were prepared in such concentrations that when mixed, the concentration would represent conditions just below saturation. After mixing, crystallization was carried out in the usual way. The mechanical properties of the LiF were similar to those reported by Sears.

11,301 PREPARATION OF SINGLE-CRYSTAL BORON by C. P. Talley (Texaco); *J. Appl. Phys.*, Vol. 32, pp. 1787-1788 (L), Sept. 1961

The preparation of a single-crystal of β -rhombohedral B 1.5 mm

in diameter and 1 cm in length by floating-zone melting using electron bombardment heating under vacuum is described. Details of the zoning technique are given. The starting boron nodes were prepared by chemical vapor plating onto 25- μ -diameter tungsten filaments at incandescent temperatures with BBr₃ and hydrogen. The progress of purification by floating refining should be easily observable by quantitative x-ray absorption measurements.

11,302 PREPARATION OF GALLIUM PHOSPHIDE CRYSTALS AND THEIR ETCH PATTERN by S. Iizima and M. Kikuchi (Electrotech. Lab.); *J. Phys. Soc. Japan*, Vol. 16, p. 1783 (L), Sept. 1961

A technique for preparing crystals of GaP and the etching characteristics of these crystals are discussed. A quartz tube closed at one end and sealed at the other end with quartz wool is placed within another quartz tube and is heated in a flowing argon gas. Ga at one end of the inner tube is heated at 1200°C and P at the other end is heated at 150° to 400°C. After twenty hours, the furnace is shut off and is cooled to room temperature. Plate-shaped crystals of GaP about 0.3 mm thick form in the Ga. The excess Ga can be removed by treating with hot dilute HCl. When the crystal surfaces, which are (111) faces, were etched in a mixture of HNO₃ and HF for 15 minutes, a characteristic pattern similar to that formed on a Ge (111) face by etching in superokol was observed on one face. No characteristic pattern was observed on the opposite face. It is suggested that the face on which the etching produces a pattern may be the surface in which the Ga atoms are on the outside of the double layer.

Preparation of:

InP - See 11,292

GaSb-InSb Alloys - See 11,335

Alloys in the HgSe-HgTe System - See 11,357

Alloys in the Tl-Sb-Se System - See 11,374

Solid Solutions of HgTe-HgSe, HgTe-HgS, and HgSe-HgS - See 11,373

FERRITE AND FERROMAGNETIC CRYSTALS

11,303 METHOD OF MAKING YTTRIUM-ALUMINUM-IRON GARNETS by B. A. Calhoun and W. L. Shevel, Jr. (IBM); U.S. Pat. 3,006,856, Issued Oct. 31, 1961

The preparation of low magnetic moment yttrium aluminum iron garnets suitable for use in high speed computer switching devices is discussed. The essential feature of the method is the sintering of the garnet constituents in the temperature range 1440°-1470°C in an oxidizing atmosphere and rapidly quenching the product to room temperature. A garnet with $B_s = 190$ gauss, $S_w = 0.12$ oe- μ sec, $B_r/B_s = 0.7$, and $H_R = 3.8$ oe can be prepared by presintering powders of Y₂O₃, Al₂O₃, and Fe₂O₃, sintering the product at 1450°C in an oxygen atmosphere, and quenching the resulting garnet to room temperature in two minutes.

11,304 METHOD OF PREPARING A MAGNETIC SOUND CARRIER by S. A. Troelstra and J. A. W. van Laar (Philips); U.S. Pat. 3,003,965, Issued Oct. 10, 1961

A technique for producing magnetic recording layers which exhibit low noise levels is described. The magnetic powder is coated with a derivative of phosphoric acid, the coated powder is dispersed in a hardenable organic liquid, and the

FERRITE AND FERROMAGNETIC CRYSTALS (Cont'd)

liquid is hardened. The tendency of the particles to form aggregates is reduced. Uncoated powder can also be mixed in an organic liquid containing the phosphoric acid derivative. Suitable derivatives of phosphoric acid are the mono- and diortho-phosphoroacid esters such as the esters of ortho-phosphoric acid and butanol-1, butanol-2, isobutanol-1, n-pentanol-1, n-hexanol-1, 2-ethylhexanol-1, decanol-1, phenol, cresol (o, m, and p), xylanol, and cardanol. Other suitable derivatives of phosphoric acid are the phosphonic acids such as mono- and dihexanephosphonic acid, mono- and di-styrene-phosphonic acid and di-benzylphosphonic acid.

11,305 PROCESS FOR MAKING COMPOSITE-FERRITES by L. G. G. Van Uitert (Bell Labs.); U.S. Pat. 3,002,929, Issued Oct. 3, 1961

The preparation of ferrites which exhibit resonance absorption of microwaves over a broad band of microwave frequencies is described. Ferrites having resonance peaks at several separated frequencies over the band of frequencies have been prepared. The ferrites are ground and mixed in the desired proportions, with the mixing carried out for a time which will not reduce the longest dimension of the ferrite particle below 0.01 cm. The mixture is then formed by pressing and firing at temperatures and times long enough to sinter the compact but not long enough for diffusion sufficient to homogenize the material to take place. An example of the preparation of a ferrite containing five ferrites is given.

11,306 MAGNETIC ELECTRODEPOSITS OF COBALT-PHOSPHORUS by J. S. Sallo and J. M. Carr (Honeywell Res. Ctr.); *J. Electrochem. Soc.*, Vol. 108, p. 173C (A), Aug. 1961

The preparation of electrodeposited films of cobalt-phosphorus having coercivities ranging from less than 50 oe to more than 1500 oe was described. The magnetic properties are independent of the substrate. Chemical composition, crystallographic orientation, and electron microscopy including Bitter Pattern studies are related to the observed coercive force. Conditions for preparing materials within this range of coercivity, including materials with stepped hysteresis loops, are described and related to the chemistry of the system.

11,307 EFFECTS OF SACCHARIN ON THE STRUCTURAL AND MAGNETIC PROPERTIES OF IRON-NICKEL FILMS by R. S. Smith, L. E. Godycki, and J. C. Lloyd (IBM); *J. Electrochem. Soc.*, Vol. 108, pp. 996-998, Oct. 1961

The effect of saccharin in the plating bath on the structural properties of electrodeposited iron-nickel films is discussed. It was found that the surfaces of films plated from saccharin-free solutions are much rougher than films plated from solutions containing saccharin; that when saccharin is present in the plating bath, the crystal size is relatively independent of pH between 2.1 and 3.1; and that saccharin reduces the occluded gas in the film. The reduction of gas in the films results in a reduction of the average strain in the film and consequently a reduction of H_c , the coercive force of the films.

11,308 AN INVESTIGATION OF THE CRYSTAL STRUCTURE AND MAGNETIC PROPERTIES OF COBALT NICKEL PLATINGS FROM A COMBINATION SULFATE/CHLORIDE BATH WITH SACCHARIN AS AN ADDITIVE by H. F. Quinn, M. Sulich, and J. Manley (IBM); *J. Electrochem. Soc.*, Vol. 108, p. 174C (A), Aug. 1961

The crystal texture and magnetic properties of platings prepared in a cobalt chloride/nickel sulfate bath containing saccharin and the additive agent were discussed. The composition, texture, and magnetic properties of the platings as a function of varying ac/dc ratio for each of four pH values are reported.

11,309 A METHOD OF PREPARING IRON-NICKEL FILMS AND SOME OF THEIR PROPERTIES by P. Kuttner and D. Clemson (Burroughs); *J. Electrochem. Soc.*, Vol. 108, p. 173C (A), Aug. 1961

The production of films of 1000 Å thickness with excellent anisotropy ($H = 1.2$ oe), and coercivity of 0.5 oe from an aqueous bath of nickel and iron sulfate with addition agents was described. Plating is done in a magnetic field. The film composition is 95 per cent Ni, 5 per cent Fe. Without addition agents, the composition and magnetic properties of the films change. However, the magnetic properties cannot be explained on the basis of composition alone.

Preparation of Plated Co and Ni Films - See 11,399

11,310 SOFT MAGNETIC MATERIAL by R. G. Parker; U.S. Pat. 2,992,990, Issued July 18, 1961

The preparation of magnetic material suitable for use in high frequency cores is described. Fe_2O_3 , ZnO , MnO_2 , SiO_2 , and talc ($MgSiO_3$) are mixed in an organic binder to produce a plastic mass. The mixture is vacuum degassed and extruded or pressed to the desired shape. The core is then sintered at a temperature in the range 2160° - 2240°F in air or in a gas kiln and cooled rapidly, e.g., at about 25°C per min. The use of the talc causes fluxing at a lower temperature than with pure SiO_2 . The core material is very dense, has low volume resistivity ($\approx 1 \times 10^{-1}$ ohm-cm) and a high permeability and is surrounded by a thin, high resistance layer having a volume resistivity in excess of 10^8 ohm-cm. The preparation of a similar magnetic material from a zinc oxide-iron oxide-silica pigment is also described.

11,311 MANUFACTURE OF METAL OXIDES AND OF FERRITES by S. E. Buckley and D. H. Owen (Intl. Stand. Elect.); U.S. Pat. 3,000,828, Issued Sept. 19, 1961

An economical process for the preparation of pure Fe_2O_3 is described. Iron powder is heated in flowing steam in the temperature range 300° to 650°C, the resulting product is milled in distilled water, and the powder is dried and calcined in air at between 150° and 1000°C. The temperature for heating in steam should not exceed 650°C because the Fe_2O_3 produced at higher temperatures cannot be used in the preparation of ferrites. Optimum results are obtained by heating at 450°C for 3 hours. The Fe_2O_3 may be prepared by itself or as one constituent of a mixture of metallic oxides. The preparation of the oxide and its use in the preparation of ferrites are shown by a number of examples.

11,312 SQUARE LOOP CADMIUM-NICKEL FERRITES by B. R. Eichbaum (IBM); U.S. Pat. 3,006,853, Issued Oct. 31, 1961

Cadmium nickel ferrites developed for use in cores whose magnetic state can be determined by surface potential difference measurements during switching are described. The ferrites, which have a low resistivity and a low dielectric constant, are prepared by sintering mixtures consisting of 5-35 mole per cent CdO, 10-35 mole per cent NiO, and 50-68 mole per cent Fe_2O_3 . The preparation of a particular ferrite by heating a mixture of 5 mole per cent CdO, 35 mole per cent NiO, and

FERRITE AND FERROMAGNETIC CRYSTALS (Cont'd)

0 mole per cent Fe_2O_3 in an uncovered platinum boat at 1200°C for one hour is described. A ferrite prepared by heating 12 mole per cent CdO , 33 mole per cent NiO , and 55 mole per cent Fe_2O_3 in an uncovered boat exhibited a resistivity of $4 \times 10^5 \text{ ohm-cm}$ and a dielectric constant of 20 at 10^4 cps and 15 at 10^6 cps .

1,313 PROCESS OF MANUFACTURING TERNARY FERRITES CONTAINING MANGANESE AND ZINC by J. Peyssou and V. Vassiliev (Steatite Res.); U.S. Pat. 3,007,874, Issued Nov. 17, 1961

The preparation of Mn-Zn ferrites is described. A mixture consisting of powdered oxides, oxalates, carbonates, acetates, or other salts of Mn and Zn and of wet ferric oxide monohydrate, is heated rapidly to the presintering temperature of 850°C in an oxidizing atmosphere. The presintering is carried out for about twenty min. The product is ground, molded with a binder, for example by pressing or extruding, and then sintered at temperatures above 1250°C in an atmosphere having a high water vapor content. Several specific examples of the process are given.

1,314 PRODUCTION OF MAGNETIC FERRITE BODIES by J. J. Schnettler (Bell Labs.); U.S. Pat. 3,004,918, Issued Oct. 17, 1961

The preparation of Mn-Zn ferrites with temperature-independent permeability is described. The constituents of the ferrite, less the Fe_2O_3 , are mixed and sintered at 800° to 1000°C for 10 to 20 hours to produce a homogeneous single phase solid solution. The sintered material is mixed with the Fe_2O_3 , ball milled to produce particles of about 1μ , pressed, and fired in an atmosphere containing between 0.5 and 2 per cent oxygen by volume at a temperature between 1025° and 1200°C . The firing time is controlled so that a limited amount of diffusion and ferrite formation takes place. The product contains between 66 2/3 and 75 atom per cent Fe. The unreacted Fe_2O_3 provides the equivalent of an air gap.

1,315 METHOD FOR PREPARING NICKEL-ZINC FERRITES by H. Lessoff (RCA); U.S. Pat. 3,009,880, Issued Nov. 21, 1961

A technique for increasing the initial permeabilities and reducing the magnetic losses of nickel zinc ferrites is described. Between 0.001 and 2.0 mole per cent of a compound of Mo such as molybdenum trioxide, MoO_3 , is mixed with the other constituents of the ferrite. The mixture is presintered, ground, shaped, and sintered in an oxygen atmosphere at between 1200°C and 1450°C . Other Mo compounds such as the chloride, amide, oxychloride, oxybromide, hydroxide, and sulfide of Mo can be used. Additions of small amounts of compounds of Cu, Co, or V also produce similar changes in the initial permeability and the loss characteristics of the ferrites.

1,316 PROCESS OF HEAT TREATING FERROMAGNETIC MATERIAL by K. J. Sixtus (Indiana Genl.); U.S. Pat. 3,001,943, Issued Sept. 16, 1961

The preparation of a ferromagnetic material which is suitable for use in permanent magnets and which exhibits a high coercive force and a high maximum useable magnetic energy is described. A mixture of Fe_2O_3 and BaO , SrO , or PbO is fired at a temperature between 2300° and 2500°F . The oxides of Ca, Co, Cr, Al or Ti can also be included. The crystals formed by prefiring should be $1 - 200 \mu$ in their largest dimensions.

The resulting product is crushed and ground until the particles are about one μ in their longest dimension. Compacts of these particles are formed under high pressure while the particles are oriented by a strong magnetic field. The compact is then sintered at the appropriate temperature. After cooling to room temperature the compact is again heated at a temperature below the sintering temperature in a mildly oxidizing or inert atmosphere. Good results have been obtained by cooling the sintered compact at a rate exceeding 50°F per minute. The final heat treatment can also be carried out before the compact has cooled to room temperature.

11,317 TWO-PHASE PERMALLOY FOR HIGH-SPEED SWITCHING by E. A. Nesbitt and E. M. Gyorgy (Bell Labs.); J. Appl. Phys., Vol. 32, pp. 1305-1308, July 1961

A series of two-phase Permalloy alloys suitable for use in switching applications is described. The alloys are prepared by adding 2-14 per cent gold to Permalloy, annealing at the solution temperature of 900°C , and then cooling rapidly. Tapes 0.014 - 0.00013 in thick are cold rolled and the material is annealed at $600^\circ - 650^\circ\text{C}$. Some alloys have switching times approximately four times faster than that of the standard Permalloy composition. Alloys containing 7 per cent gold and 14 per cent gold yield square hysteresis loops having coercive forces of at least 1.7 and 4.3 oe, respectively. For the 7 per cent gold alloy, the threshold for rotational flux reversal is 2.5 oe.

11,318 LARGE GARNETS PAVE WAY FOR NEW DEVICES; by Staff; Electronics, Vol. 34, pp. 70-73, July 28, 1961

A method of growing and polishing YIG crystals is described. By use of an improved growth process, large single crystals weighing 85 - 95 grams have been obtained. The availability of ZnO crystals and their piezoelectric properties are also mentioned.

11,319 FERRIMAGNETIC GARNET by S. Geller (Bell Labs.); U.S. Pat. 3,006,854, Issued Oct. 31, 1961

Solid solutions of yttrium iron garnet ($\text{Y}_3\text{Fe}_5\text{O}_{12}$) and other rare earth iron garnets with the garnets $\text{YM}_2\text{Zr}_2\text{Fe}_3\text{O}_{12}$ or $\text{YMHf}_2\text{Fe}_3\text{O}_{12}$, where M represents Ca, Ba, or Sr, are discussed. The resulting garnet exhibits, within a certain range of compositions, a saturation magnetic moment which is larger than that of the rare earth iron garnet. A solid solution of $\text{Y}_3\text{Fe}_5\text{O}_{12}$ and $\text{YCa}_2\text{Zr}_2\text{Fe}_3\text{O}_{12}$, for example, exhibits magnetic moments larger than that of $\text{Y}_3\text{Fe}_5\text{O}_{12}$ up to solutions containing 50 mole per cent $\text{YCa}_2\text{Zr}_2\text{Fe}_3\text{O}_{12}$. A theoretical explanation for this effect is presented and the preparation of specific garnets is described.

11,320 POLYCRYSTALLINE GARNET MATERIALS by L. G. G. van Uitert (Bell Labs.); U.S. Pat. 3,003,966, Issued Oct. 10, 1961

The preparation of high density, high resistivity (above 10^{12} ohm-cm) garnets is described. The garnets have the composition $\text{A}_3\text{B}_5\text{O}_{12}$, where A is Y, or one or more of the rare earths with atomic number between 62 and 71, or a mixture of Y with one or more of these rare earths, and B is Fe, or Fe partly substituted by trivalent elements such as Ga, Al, Sc, In, or Cr. High density, high resistivity garnets result from mixing cupric Cu and pentavalent V with the other constituents of the garnet in the ratio of 2 moles of the Cu ion to one mole of the V ion. The mixture is presintered, ground and pressed into the desired shape. The sintering is then carried out in air, oxygen, a

FERRITE AND FERROMAGNETIC CRYSTALS (Cont'd)

mixture of these, or in some other oxidizing atmosphere at a firing temperature between 1200° and 1350°C, and preferably between 1250° and 1325°C. For a given firing temperature, a sample having a higher Cu-V content than another will result in a higher density product in a shorter firing time.

Preparation of High Permeability Mn-Ferrites - See 11,522

Preparation of Mg-Mn Ferrites - See 11,521

PARAMAGNETIC MATERIALS

11,321 PROCESS FOR GROWING AND APPARATUS FOR UTILIZING PARAMAGNETIC CRYSTALS by L. G. G. van Uitert (Bell Labs.); U.S. Pat. 3,003,112, Issued Oct. 3, 1961

The growth of single crystals of calcium, magnesium, zinc, cadmium, strontium, or barium tungstate containing paramagnetic ions, which are suitable for use in masers, is described. A mixture of the tungstate or a compound which will react with tungstic anhydride to form the tungstate and a compound containing the paramagnetic ion are heated in an alkali metal ditungstate flux such as sodium ditungstate at a temperature between 900° and 1450°C for up to 5 hrs. The molten solution is then cooled at a rate between 0.1° and 25°C per hour to cause the solution to solidify. The crystals are then quenched to room temperature and are separated by a solvent such as sodium hydroxide. Specific examples of the preparation of the crystals are given.

Preparation of LaCrO₃ - See 11,412

CRYSTAL SURFACES

(Including Surface Processing and Treatments)

11,322 MEASUREMENT OF THE THICKNESS AND REFRACTIVE INDEX OF SURFACE OXIDE FILMS ON SEMICONDUCTOR MATERIALS by G. R. Booker and C. E. Benjamin (Westinghouse); J. Electrochem. Soc., Vol. 108, p. 175C (A), Aug. 1961

The application of monochromatic-light interferometry to the measurement of the thickness and refractive index of surface oxide films on semiconductor materials is described. Interference fringe patterns may be obtained by comparing either the top surface or the bottom surface of a wedge-shaped step in the oxide film with an external reference plane, or by comparing the two surfaces of the wedge with one another. Capabilities and accuracies obtainable using these three systems are discussed. A novel method is described for the rapid measurement of oxide film thicknesses on Si; the method uses simple equipment and is independent of surface roughness.

11,323 A METALLOGRAPHIC INVESTIGATION OF THE DAMAGED LAYER IN ABRADED GERMANIUM SURFACES by E. N. Pugh and L. E. Samuels (Austl. Def. Sci. Service); J. Electrochem. Soc., Vol. 108, pp. 1043-1047, Nov. 1961

An investigation by a metallographic taper-sectioning technique of the structure of the damaged layer produced on {111} surfaces of Ge by several abrasion processes is discussed. The study confirms that the abrasion process involves both cleavage and noncrystallographic fracture and establishes that the sur-

face layers contain many cracks initiated by these fracture processes. Dislocations are not introduced into the surface layers. Measurements of the depth of the layers containing the damage cracks are in sufficiently good agreement with estimates of the depth of damage made by established methods to indicate that the cracked layer is the classical damaged layer.

Polishing YIG Spheres - See 11,318

11,324 DISLOCATION ETCH PITS IN POLISHED LEAD TELLURIDE by G. P. Tilly (Assoc. Elect. Ind.); Brit. J. Appl. Phys., Vol. 12, p. 524(L), Sept. 1961

A method for polishing and etching PbTe single crystal surfaces other than the {100} is described. The electrolytic polishing technique is similar to that of Schmidt. The specimen is prepared by polishing on a 700-mesh carborundum powder. It is preheated in a water bath to 70°C to reduce thermal shock, and after removal from the electrolyte, is immediately dipped in alcohol to suppress the formation of oxide layers. Etching must be performed while the specimens are still fresh. Well defined dislocation etch pits are readily revealed and dislocation densities, subgrain structure and deformation patterns may be examined.

Etching Characteristics of GaP Crystals - See 11,302

Junction Examination with Stain Etch - See 11,299

11,325 CHARACTERISTICS OF THE {111} SURFACES OF THE III-V INTERMETALLIC COMPOUNDS III. THE EFFECTS OF SURFACE ACTIVE AGENTS ON InSb AND THE IDENTIFICATION OF ANTIMONY EDGE DISLOCATIONS by M. C. Lavine, H. C. Gatos, and M. C. Finn (Lincoln Lab.); J. Electrochem. Soc., Vol. 108, pp. 974-980, Oct. 1961

An investigation of the effects of inorganic and organic surface active agents on the behavior of the InSb {111} surfaces in oxidizing etchants is discussed. It was found that specific adsorption of these agents leads to a decrease in the dissolution rate of InSb and pronounced changes in the microstructure of the {111} surfaces. In the presence of an organic sulfide it was possible to develop etch pits which were identified with Sb edge dislocations on the {111} surfaces. This result was verified by means of plastic deformation experiments. Electrical measurements at 78°K suggest that Sb dislocations serve as electron donors whereas In dislocations serve as electron acceptors.

11,326 ELECTRODEPOSITION OF MOLTEN METALS AND ALLOYS FROM GLYCERINE SOLUTIONS by G. L. Schnable (Philco); J. Electrochem. Soc., Vol. 108, pp. 964-969, Oct. 1961

The electrodeposition on small wires and strips of several molten metals and alloys including In, Sn, and Bi, and alloys containing In, Sn, Bi, Cd, Tl, or Pb as a principal constituent from glycerine solutions of metal halides is discussed. Molten metals and alloys which have liquidus temperatures up to about 270°C can be electrodeposited. Because of the extremely high current densities (20 to 50 amp/cm²) utilized, metals widely separated in the electromotive series can be readily codeposited. Electrodeposition can be extremely rapid, and local heating at the cathode during deposition permits deposition from a bath operated at a temperature considerably lower than

CRYSTAL SURFACES (Cont'd)

the liquidus temperature of the electrodeposited solder. The coating of plating solution which remains on the lead when it is removed from the plating solution serves as a flux when the coated wire is bonded or microalloyed to a semiconductor. Leads prepared by this technique have been used in the fabrication of surface barrier transistors, microalloy transistors, and microalloy diffused-base transistors.

11,327 FURTHER STUDIES OF THE TRANSITION REGION OF A COBALT SULFATE ELECTROLYTE by H. F. Quinn (IBM); J. Electrochem. Soc., Vol. 108, pp. 173C-174C (A), Aug. 1961

A uniform transistional change in texture and magnetic properties of electrodeposited Co films through a pH range of from 3.8 to 4.8 of the dilute sulfate bath was reported. It was shown that the change in coercivity of the plating is not directly associated with the textural changes. The nature of the alteration in the crystal growth process at the cathode is considered in terms of the theory of Willman and others. In particular, it is shown that the type and surface finish of the substrate are not significant controlling factors in the growth process.

11,328 THE EFFECT OF PRESSURE ON THE ELECTROLESS DEPOSITION PROCESS by J. S. Sallo, J. I. Swenson, and J. M. Carr (Honeywell Res. Ctr.); J. Electrochem. Soc., Vol. 108, p. 174C (A), Aug. 1961

The effect of hydrostatic pressure on the rate of electroless Ni deposition was discussed. Two classes of acid baths exist, depending on whether the rate is increased or decreased. This difference explains conflicting literature reports. One of these systems is shown to be diffusion controlled. In the other case, the results indicate that the rate is dependent on the effective catalytic area which is exposed to the system and free of hydrogen gas.

11,329 THE INFLUENCE OF ADSORBED MATERIAL ON THE GROWTH OF THE METALLIC LATTICE by T. P. Hoar (U. Cambridge); J. Electrochem. Soc., Vol. 108, p. 170C (A), Aug. 1961

The role of addition agents in electrodeposition was discussed. Addition agents, whether used for brightening, leveling, refining of grain size, or reduction of tensile stress in electrodeposits, are commonly held to act "by adsorption." An attempt at discriminating between different kinds of adsorption according to the lattice structure and electrochemical characteristics of the metal being deposited, and the size, shape, and polarizability of the molecule being adsorbed was described. By means of the discrimination process developed, empirical knowledge of the various kinds of addition agents can be partially codified and explained.

Metallizing Contacts to Semiconductor Surfaces - See 11,506

ENVIRONMENTAL EFFECTS

Effect of Heat Treatment on Resistance of Granular Carbon - See 11,365

Effect of Plastic Deformation Upon the Magnetostriction Constant of Ni - See 11,406

11,330 MECHANISM OF THE INDIVIDUAL ELECTRON ENERGY LOSSES IN GERMANIUM by N. B. Gornyi (Leningrad Elect. Engrg. Inst.); Soviet Phys.-Solid State, Vol. 3, pp. 507-509, Sept. 1961

An analysis of scattered electron energy distributions obtained experimentally from a vacuum-evaporated germanium thin film is presented. The energies of five of the peaks obtained are in good agreement with theoretical values due to Hayasi. The energy of one of the remaining peaks corresponds to that of plasma oscillations, while another peak has energy corresponding to neither of the above. Two peculiarities of this peak contrasted sharply with the behavior of the others as the incident electron energy increased. It therefore seems that this peak is caused by a different mechanism and an explanation is proposed.

Divacancies Produced in Si by Electron Irradiation - See 11,281

Neutron-Irradiated Fused Silica - See 11,475

Effects of Gamma Irradiation on Polyethylene - See 11,344

Conductivity in Co⁶⁰ of Irradiated CdS Crystals - See 11,367

Radiation Defects in Ge - See 11,339

SOLID STATE PHYSICS

GENERAL

11,331 SEMICONDUCTOR ALLOYS by F. Herman, M. Glicksman, and R. H. Parmenter (RCA Labs.); Prog. in Semicon., Heywood, London, 1957, Vol. 2, pp. 3-33

Recently published work on the effect of disorder on the electronic energy levels, the lattice vibrational spectra, and the electrical, magnetic, thermal, and optical properties of semiconductor alloys is reviewed. [78 references]

Review of Semiconducting Alloys - See 11,246

11,332 NON-CRYSTALLINE, AMORPHOUS AND LIQUID ELECTRONIC SEMICONDUCTORS by A. F. Ioffe and A. R. Regel (Inst. Semicon., Leningrad); Prog. in Semicon., Heywood, London, 1960, Vol. 4, p. 237

Experimental investigations of the semiconducting properties of substances with a disrupted long-range order (such as liquids, solid solutions, defective structures, and amorphous materials) are reviewed. It is shown that the electrical properties of these substances are well explained qualitatively by ideas based on the decisive role of the short-range order, i.e., on the character of the chemical bonds between neighbors. Data on the temperature dependence of the electrical conductivity in the liquid and solid states are given for LiCl, NaCl, KCl, TiS₂, Bi₂O₃, Sb₂S₃, V₂O₅, Fe₂S-Cu₂S, V₂O₅-CuO, V₂O₅-Fe₂O₃, Si, Ge, GaSb, InSb, HgTe, HgSe, CdTe, GaSb, InSb, Se, Te, Te-Se, Bi₂Te₃, Bi₂Se₃, NiTe₂, CoTe₂, FeTe₂, PbTe, PbSe, CuTe, Cu₂Se, and ZnSb. Curves showing carrier mobility as a function of composition for the systems PbTe-PbSe, Bi₂Te₃-Bi₂Se₃, Bi₂Te₃-Sb₂Te₃, and Bi₂Te₃-Bi₂S₃ are also given. [194 references.]

CRYSTAL PHYSICS
(Including Energy Band Structure)

11,333 SPECULATIONS ON THE ENERGY BAND STRUCTURE OF Ge-Si ALLOYS by F. Herman (RCA Labs.); Phys. Rev., Vol. 95, p. 847, 1954

A possible explanation for the change in energy gap with a change in concentration ratio for Ge-Si alloys is proposed. Theoretical band structure diagrams for the pure elements are shown and from these an explanation of empirical energy gap changes in alloys is surmised.

11,334 OPTICAL INVESTIGATION OF THE BAND STRUCTURE OF Ge-Si ALLOYS by J. Tauc and A. Abraham (Inst. Tech. Phys., Czech. Acad. Sci.); J. Phys. Chem. Solids, Vol. 20, Nos. 3-4, pp. 190-192, Aug. 1961

Measurements of the reflection spectra of Ge-Si alloys at room temperature in the photon energy range 2 - 5 ev are presented. The curve giving the dependence of the energy of the first characteristic peak in the reflection spectrum on the composition of the alloy shows a break at about 79 atomic per cent of Si. The consequences of this observation for the band structure are discussed.

Energy Band Structure in Ge Grain Boundaries - See 11,286

11,335 OPTICAL ENERGY GAP VARIATION IN THE GaSb-InSb SYSTEM by J. C. Woolley, J. A. Evans, and C. M. Gillett (U. Nottingham); Proc. Phys. Soc., Vol. 74, pp. 244-248, Sept. 1959

Following a discussion of the preparation of alloys in the GaSb-InSb system, an infrared investigation of the variation of optical energy gap in the GaSb-InSb system is described. X-ray data which show the variation in composition and the degree of homogeneity of sections cut from long rod ingots produced by very slow directional freezing techniques are given. The results of infrared transmission measurements on these sections are presented together with a graph of the variation of wave length for the onset of transmission, interpreted as optical energy gap, as a function of composition. The form of this graph is discussed briefly.

11,336 SOME OPTICAL PROPERTIES OF Bi_2Te_3 - Bi_2Se_3 ALLOYS by I. G. Austin and J. Sheard (GE Ltd.); J. Electronics Control, Vol. 3, pp. 236-237, 1957

A graph of the optical energy gap of Bi_2Te_3 - Bi_2Se_3 alloys as a function of composition is given. A sharp change of slope occurs close to the composition $\text{Bi}_2\text{Te}_2\text{Se}$ although x-ray data give no indication of super-lattice or compound formation at this composition. It is concluded that an explanation of the kind proposed by Herman for Ge-Si alloys may be applicable.

11,337 SOME PROPERTIES OF GERMANIUM-SILICON ALLOYS by E. R. Johnson and S. M. Christian (RCA Labs.); Phys. Rev., Vol. 95, pp. 560-561, 1954

Analysis of x-ray, optical, and chemical properties of homogeneous alloys of Ge and Si is reported. Samples were homogenized at high temperatures to the precision of x-ray determination. Concentration ratios from 85 to 0.7 mole per cent Si were determined by polarographic analysis for Ge. Lattice constant (x-ray determined) and energy gap width (optically determined) are plotted vs Si concentration.

11,338 THE FORMATION OF MIXED CRYSTALS IN $\text{A}^{\text{III}}\text{B}^{\text{V}}$ COMPOSITIONS [in German] by O. G. Folberth (Siemens AG); Z. Naturforsch., Vol. 10a, pp. 502-503, 1955

The possibility of expanding the range of ΔE values by formation of mixed crystals between $\text{A}^{\text{III}}\text{B}^{\text{V}}$ compositions is discussed. In the quasi-binary systems InAs-InP and GaAs-GaP a continuous series of mixed crystal structures is present. Therefore it is possible to obtain $\text{A}^{\text{III}}\text{B}^{\text{V}}$ compounds with arbitrary ΔE between 0.33 and 1.25 ev for InAs-InP, and 1.25 and 2.25 ev for GaAs-GaP. Formation of mixed crystals occurs in these systems although the lattice constants of these crystals differ more than lattice constants of the system GaSb-AlSb which was examined before with negative results.

Determination of Forbidden Band Width in Ge - See 11,484

11,339 THE ENERGY SPECTRUM OF DEFECTS PRODUCED BY γ -RAYS IN GERMANIUM by N. A. Vitovskii, T. V. Mashovets, S. M. Ryvkin, and V. P. Sondaevskii; Soviet Phys.-Solid State, Vol. 3, pp. 727-729 (L), Sept. 1961

The positions of three of the four acceptor levels of radiation defects in Ge are discussed. The uppermost four levels of a defect should be empty at absolute zero. These layers may be filled by electrons from impurity donors in Ge doped with elements of group V. By altering the concentration of defects it is possible to obtain different ratios of the defect concentration and the impurity donor concentration. The temperature dependence of the Hall constant of samples of all five possible ways of occupation of the uppermost defect levels in the forbidden band have been measured. Results indicate that either all the defect levels are of acceptor type, or some are donor levels with an appropriate number of acceptor levels below ($E_v + 0.02$) ev. Values for the four bands are given.

11,340 ENERGY-LEVEL MODEL FOR HIGH-RESISTIVITY GALLIUM ARSENIDE by J. Blanc and L. R. Weisberg (RCA Labs.); Nature, Vol. 192, pp. 155-156 (L), Oct. 14, 1961

A model which explains the existence of high resistivity gallium arsenide without requiring a high degree of compensation, and therefore with no need for automatic compensation, is discussed. High resistivity occurs when $N_A > N_D$ and $N_{DD} > (N_A - N_D)$, where N_A is the density of acceptors, N_D is the density of shallow donors, and N_{DD} is the density of deep donors. The model predicts a wide range of resistivities and three conductivity ranges, in agreement with the results of Gooch et al. It is pointed out that no p-type GaAs is produced during the growth of undoped GaAs. The model accounts for the experimental observation that the activation energy in n-type GaAs can be greater than half the band gap.

Fermi Level of GaAs - See 11,359

11,341 3d BAND STRUCTURE OF Cr by M. Asdente (Politec., Milano) and J. Friedel (Fac. Sci., Orsay); Phys. Rev., Vol. 124, pp. 384-390, Oct. 15, 1961

The electronic structure of the 3d band in Cr is calculated in the tight-binding approximation. The effect of the nearest-neighbor interaction and of the second-nearest-neighbor interaction on the energy surfaces in the Brillouin zone and on the density-of-states curve $g(E)$ is investigated. By means of group theory, an analysis of the electron levels and of the eigenfunctions is performed in some particular points of the Brillouin zones; bonding and antibonding characters are found,

together with different space distributions, for the eigenfunctions at the bottom and the top of the band. A comparison with other theoretical results suggests that the details of the chosen potential do not influence the general trend of the $g(E)$ curve very much; a satisfactory comparison of theory with experimental results is obtained.

Energy Band Structure of:

Ge	- See 11,362
Bi	- See 11,395
Te	- See 11,391
CdS	- See 11,367
CdSb	- See 11,436
In(As _y P _{1-y})	- See 11,396

11,342 APPROXIMATE CALCULATION OF FREQUENCIES OF LOCALIZED VIBRATIONS by O. Litzman and J. Cely (Brno U.); *Czech. J. Phys.*, Vol. 11B, pp. 320-323, 1961

Calculations of the frequencies of localized vibrations in a crystal are discussed. Since an exact calculation of these frequencies in a crystal with defects is difficult, only the simplest cases have been derived. An approximate calculation, confined to computing the frequencies of a system composed of several atoms in the neighborhood of the defect, is given. The interaction between this system and the other atoms of the lattice, which however are immobile in this approximation, is taken into consideration. Since the analytical estimate of the approximation is very rough, the approximate and exact calculations have been compared for some concrete cases. It is clear from these calculations that the use of the proposed approximation leads to good results.

11,343 ELECTRON DISTRIBUTION IN KMnF₃, KFeF₃, KCoF₃, AND KNiF₃ by A. Okazaki and Y. Suemune (Kyusyu U.); *J. Phys. Soc. Japan*, Vol. 16, p. 1474(L), July 1961

The electron distributions in KMnF₃, KFeF₃, KCoF₃, and KNiF₃, determined by x-ray analysis, are reported. The [001] projections of the electron distribution obtained by the F₀ synthesis are discussed. In all cases, the electron distributions around F⁻ ions are elongated in the direction perpendicular to the 3d metal-fluorine-3d metal bonds.

ELECTRICAL PROPERTIES

DIELECTRIC PROPERTIES

11,344 INFLUENCE OF GAMMA RADIATION ON THE DIELECTRIC PROPERTIES OF CERTAIN ELECTRICAL INSULATION MATERIALS. IV. POLYETHYLENE [in Russian] by K. A. Adop'ianov, B. I. Vorozhtsov, and N. I. Ol'shanskaia (SFTI, Tomsk U.); *Izv. VUZ, Fizika*, No. 4, pp. 156-159, 1960

Results of an investigation of the electrical properties of polyethylene, both non-irradiated and gamma irradiated, are presented. It is shown that doses of radiation up to 10⁵ roentgens do not cause structural changes in polyethylene. Irradiation at low temperatures leads to residual changes in ρ_v and $\tan \delta$ because of the ionization of the material.

Dielectric Constant of LiF - See 11,464

11,345 PRE-THERMAL BREAKDOWN PROCESSES II. ON THE THEORY OF THE INHOMOGENEOUS CURRENT DISTRIBUTION AT HIGH ELECTRICAL LOADS [in German] by K. W. Böer, E. Jahne, and E. Nebauer (Humboldt U.-Germ. Acad. Sci.); *Phys. Status Solidi*, Vol. 1, No. 3, pp. 231-242, 1961

An investigation of the electrical and thermal behavior of a cylindrical solid dielectric for current loads below the thermal breakdown value is reported. The steady-state distributions of temperature and current density are described in relation to the electric load and an expression for the current-voltage characteristic is given in a parametric representation.

11,346 ON THE THEORY OF FERROELECTRICS OF THE BARIUM TITANATE TYPE [in Russian] by G. P. Petin (Rostov-on-Don U.); *Izv. VUZ, Fizika*, No. 2, pp. 125-131, 1961

A model theory of ferroelectrics of barium titanate type is developed. Underlying the model is the assumption that the central cation has a variable number of bonds. A discussion of a number of properties of barium titanate single crystals is presented.

11,347 INVESTIGATION OF REORIENTATION OF THE GUANIDIUM ION IN THE FERROELECTRIC C(NH₂)₃ · Al(SO₄)₂ · 6H₂O BY THE NUCLEAR MAGNETIC RESONANCE METHOD by A. G. Lundin, G. M. Mikhailov, and S. P. Habuda (Siberian Tech. Inst.); *Soviet Phys.-JETP*, Vol. 13, pp. 903-907, Nov. 1961

Detection of the reorientation of the [C(NH₂)₃]⁺ ion in the ferroelectric C(NH₂)₃ · Al(SO₄)₂ · 6H₂O at temperatures above 130°K by means of nuclear magnetic resonance is discussed. The temperature dependence of the second moment of the absorption line of a polycrystalline sample has been examined between 90° and 400°K. The height of the potential barrier for the reorientation of the C(NH₂)₃ group has been estimated and some conclusions regarding the reorientation mechanism are given.

11,348 A CONTRIBUTION TO THE STATICS OF 90° WEDGE-SHAPED DOMAINS IN BaTiO₃ CRYSTALS by J. Fousek, B. Brezina (Czech. Acad. Sci., Prague); *Czech. J. Phys.*, Vol. 11B, pp. 261-267, 1961

A study of the existence of 90° domains of wedge and parallelepiped shape in BaTiO₃ crystals of different form is discussed. On the basis of a simple model, the condition for their origin is described.

11,349 THE MOTION OF 90° WEDGE DOMAINS IN BaTiO₃ IN AN ALTERNATING ELECTRIC FIELD by J. Fousek and B. Brezina (Czech. Acad. Sci., Prague); *Czech. J. Phys.*, Vol. 11B, pp. 344-359, 1961

The motion of 90° wedge domains in BaTiO₃ in an alternating field of 50 cps is considered. The critical field, the positional hysteresis loops with double asymmetry, and the production of wedges with polarization perpendicular to the field and 180° substructure in the wedges have been studied. The differences between the behavior of the wedges and the individual 90° walls, which are caused by differences in the energy balance of these formations and by different interactions with 180° processes, are pointed out and the upper limit of contribution of the wedge motion to the initial permittivity is estimated. The results are discussed from the phenomenological point of view.

Piezoelectric Properties of ZnO - See 11,318

CARRIER PROPERTIES

11,350 CERTAIN QUESTIONS RELATED TO CURRENT-CARRIER RECOMBINATION AND GENERATION IN SEMICONDUCTORS [in Russian] by V. M. Lenchenko (Inst. Nuclear Phys. AN UzbSSR), *Izv. AN UzbSSR, Fiz.-Mate. Nauk*, No. 3, pp. 34-42, 1961

A statistical theory for certain phenomena related to current carrier recombination and generation in semiconductors is proposed. A method, similar to that of A. Einstein, is used to derive the Planck formula for the spectral distribution of thermal radiation. The computations assume the existence of forced transitions due to the effect of phonon and photon fields in addition to the spontaneous recombination transitions. Formulas are obtained for the spectral distribution of the intensity of recombination radiation in the presence of impurity levels (traps, recombination centers, etc.) in the semiconductor; for the radiation and radiationless recombination rates; for the work function under irradiation of the semiconductor by an external light source, as a function of the current-carrier injection levels, the degree of occupation of the local levels and the depth of their location.

Density and Energy Levels of Surface Recombination Centers - See 11,392

Traps in CdS - See 11,367

Traps in Semiconductors - See 11,453

11,351 ON THE NATURE OF SURFACE RECOMBINATION CENTERS IN GERMANIUM by A. V. Rzhanov, Yu. F. Novototskii-Vlasov, I. G. Neizvestnyi, S. V. Pokrovskaya, and T. I. Galkina (Lebedeva Phys. Inst.); *Soviet Phys.-Solid State*, Vol. 3, pp. 600-606, Sept. 1961

A study of surface recombination centers in Ge is reported. The sudden change in the concentration of surface recombination centers as a result of heating in vacuo has been used to investigate the nature of the process of recombination. The basis of the method used was a joint measurement of stationary photoconductivity and so-called field effect at large signals. From data obtained the dependence of surface recombination velocity on surface potential was determined. The experiment was performed on Ge; the conclusion was drawn that surface recombination is determined by the joining of several centers which make comparable contributions to the total surface recombination velocity.

11,352 CHANGES IN SURFACE RECOMBINATION CAUSED BY SORPTION OF WATER MOLECULES by G. Dorda (Czech. Acad. Sci., Prague); *Czech. J. Phys.*, Vol. 11B, pp. 406-415, 1961

The influence of the percentage content of humidity in the surrounding atmosphere on the surface recombination of Ge at room temperature is discussed. The surface conductivity and ac field effect were measured as a function of the relative humidity at the same time as the effective lifetime was determined. The cyclically varying humidity was changed in the limits of 0.5 and 80 per cent. A comparison between the results of the surface recombination and the field effect gave the values of the energies, concentration and cross section for the trapping of holes and electrons of the fast states. Analysis

was based on the assumption that all fast centers and not only those of one kind contribute to recombination. It was proved that the hysteresis of the dependence of s on ϕ during the humidity cycle can be explained on the basis of changes in concentration of all fast states due to the sorption of water molecules in the oxide layer.

Electron Effective Mass in Ge - See 11,465

Hole Effective Mass in CdSb - See 11,436

11,353 SYMMETRY PROPERTIES OF WARM ELECTRON EFFECTS IN CUBIC SEMICONDUCTORS by K. J. Schmidt-Tiedemann (Philips Res. Labs.); *Phys. Rev.*, Vol. 123, pp. 1999-2000, Sept. 15, 1961

The constant β which describes the field dependence of the mobility μ of warm electrons in the expression $\mu = \mu_0(1 + \beta E^2)$ is discussed. β is found to be anisotropic even for crystals of cubic symmetry. The directions of field strength and current density include an angle, the tangent of which is given by $E^2(\gamma_0/2) \sin \phi \cos \phi \times (1 - 3 \cos^2 \phi)$, where ϕ is the angle between the field situated in the (110) plane and the cube axis, and γ_0 is a constant. The following symmetry relations are found for silicon and germanium: $\beta_{110} = \beta_{100} - (\gamma_0/2)$, $\beta_{111} = \beta_{100} - (2\gamma_0/3)$, where the subscripts denote the direction of field strength. The theoretical results have been confirmed experimentally with n-type germanium of different impurity content.

11,354 EPITAXIAL PbS FILMS: ELECTRICAL PROPERTIES by J. D. Jensen and J. N. Zemel (U.S. Naval Ord. Lab.); *Bull. Am. Phys. Soc.*, Vol. 6, p. 437(A), Nov. 24, 1961

The properties of thin films of lead sulfide prepared by epitaxial deposition onto cleaved surfaces of NaCl were discussed. The thickness of the films ranged between 0.5 and 1.5 μ . Hall coefficient measurement showed that the films could be either n- or p-type with carrier concentrations of the order of $10^{18}/\text{cm}^3$. Hall mobilities at room temperature varied from 2 to 300 $\text{cm}^2/\text{v-sec}$ for both types; a value of 60 $\text{cm}^2/\text{v-sec}$ being obtained on the average. The highest mobility found is quite comparable to bulk mobility of 4 - 500 $\text{cm}^2/\text{v-sec}$ and the average mobility is about an order of magnitude higher than the usual evaporated PbS films. Measurements were carried out from 77° to 300°K. At high temperatures, the mobility varied asymptotically as $T^{-5/2}$. At low temperatures an approximately temperature-independent mobility appeared which severely limited the magnitude of the mobilities.

11,355 ROTATING SAMPLE METHOD FOR MEASURING THE HALL MOBILITY by F. M. Ryan (Westinghouse Res. Labs.); *Bull. Am. Phys. Soc.*, Vol. 6, Ser. II, p. 437(A), Nov. 24, 1961

A simple apparatus for measuring Hall mobilities was described. The sample to be measured is rotated in an external magnetic field. The sample thus "sees" an ac magnetic field and ac magnetic field Hall techniques may be used. Methods for obtaining dc or ac Hall output voltages were discussed. Probe misalignment voltages are rejected by this technique as they are in a standard ac magnetic field method. By using a dc magnetic field, equipment design is simplified and the ac magnetic field Hall technique may be extended to the region of high magnetic fields. Some results of rotating sample Hall mobility measurements on low mobility pressed and sintered semiconductors were given.

Mobility Ratio in CdSb - See 11,436

11,356 ON THE MOBILITY OF ELECTRONS AND HOLES IN SOLID SOLUTIONS BASED ON LEAD AND BISMUTH TELLURIDES by S. V. Airapetiants, B. A. Efimova, T. S. Stavitskaia, L. S. Stilbans, and L. M. Sysoeva (Semicon. Inst., Leningrad); *Soviet Phys.-Tech. Phys.*, Vol. 2, pp. 2009-2011, Sept. 1957

The variation with composition of electron and hole mobility in the $\text{Bi}_2\text{Te}_3\text{-Bi}_2\text{Se}_3$, $\text{Bi}_2\text{Te}_3\text{-Sb}_2\text{Te}_3$, PbTe-PbSe , and PbTe-SnTe systems is discussed. In the $\text{Bi}_2\text{Te}_3\text{-Bi}_2\text{Se}_3$ system, the electron mobility is practically unchanged and the hole mobility decreases by a factor of 6 for compositions up to 30 per cent Bi_2Se_3 . In the $\text{Bi}_2\text{Te}_3\text{-Sb}_2\text{Te}_3$ system, the mobility of the holes increases and the mobility of electrons decreases by a factor of 2 for compositions up to 50 per cent Sb_2Te_3 . In the PbTe-PbSe system, the electron mobility decreases by 25 per cent and the mobility of holes, 2.5 times. On the addition of 30 per cent SnTe to PbTe, the mobility of the electrons becomes less than that of the holes. These observations indicate that in all the solid solutions studied the electrons move within the cation sublattice and the holes move within the anion sublattice. It is concluded that to reduce the thermal conductivity of p-type compounds without reducing the mobility of the holes, the cation must be partially replaced; in n-type compounds, the anion must be replaced.

11,357 STABILITY OF CRYSTAL STRUCTURE IN THE SOLID SOLUTION SYSTEM HgSe-HgTe by O. D. Elpat'evskaja, R. A. Konikova, A. R. Regel', and I. V. Iavorskii, (USSR Acad. Sci.); *Soviet Phys.-Tech. Phys.*, Vol. 1, pp. 2091-2093, Oct. 1957

Carrier mobilities and x-ray structure analyses of HgSe , HgTe , and solid solutions of the two compounds are discussed. The specimens were prepared by fusing the starting materials in sealed, evacuated quartz ampoules and by mixing the stoichiometric amounts of Hg, Se, and Te at room temperature in a porcelain mortar. Both bulk crystals and evaporated films were investigated. Electrical measurements indicated that, depending on the evaporation method, two types of films, both of which were 6-8 μ thick, were formed. Opaque grey layers which were metallic in color exhibited carrier mobilities of 1000-3000 $\text{cm}^2/\text{volt-sec}$. Films which were transparent in the longwave section of the visible spectrum exhibited mobilities from 30 to 175 $\text{cm}^2/\text{volt-sec}$. X-ray analysis indicated that annealing produces only a very slight change in lattice constants in the HgSe-HgTe system, and that HgSe and HgTe specimens prepared by simple mechanical mixture of the components have the same crystal structure as cast specimens of the same composition.

Dependence of Faraday Ellipticity in Semiconductors on Scattering Mechanisms - See 11,463

CONDUCTIVITY

Conductivity Model for GaAs - See 11,340

11,358 MEASUREMENT OF ELECTRICAL RESISTIVITY BY A MUTUAL INDUCTANCE METHOD by R. G. Chambers and G. Park (Wills Phys. Lab.); *Brit. J. Appl. Phys.*, Vol. 2, pp. 507-510, Sept. 1961

A method whereby the electrical resistivity of a sample can be

determined from the change in mutual inductance between two coils caused by the sample is described. With simple equipment for measuring mutual inductance over a range of frequencies, the method can be used to measure resistivities greater than $2 \times 10^{-9} \text{ ohm-cm}$.

11,359 CERTAIN ELECTROPHYSICAL PROPERTIES OF GALLIUM ARSENIDE [in Russian] by A. F. Kravchenko (Novosibirsk Electrotech. Inst.); *Izv. VUZ, Fizika*, No. 3, pp. 80-87, 1961

Studies on the temperature dependence of the electrical conductivity, the thermal EMF and the Fermi level of gallium arsenide with different conductivities are reported. The effective mass and hole and electron concentrations are determined. The dependence of the Hall constant on the temperature and magnetic field is investigated. The mobility and its temperature dependence are determined. A comparison is made between experimental results and theoretical computations and certain considerations on the mechanism of current carrier scattering are given.

11,360 CHANGES IN THE ELECTRICAL RESISTANCE OF SEVERAL METALS UP TO PRESSURES OF 250,000 kg/cm^2 by L. F. Vereshchagin, A. A. Semerchan, N. N. Kuzin, and S. V. Popova (Inst. High Pressure Phys.); *Soviet Phys.-Doklady*, Vol. 6, pp. 391-392, Nov. 1961

The pressure dependence of the electrical resistance of several metals measured at pressures exceeding 100,000 kg/cm^2 is discussed. The measurements were made on wires with diameters ranging from 0.6 to 0.8 mm. In rhenium, niobium, and yttrium a smooth drop in electrical resistance was observed, with the greatest change taking place in the pressure range from 30,000 to 100,000 kg/cm^2 . No jump-like change in the electrical resistance of zirconium was observed. A sharp change in the slope of the curve was, however, observed between 90,000 and 100,000 kg/cm^2 . It is suggested that Bridgman mistook this change in slope as a jump in electrical resistance since he carried his measurements up to 100,000 kg/cm^2 . The drop in resistance in lead, tin, and cadmium up to 100,000 kg/cm^2 agrees with Bridgman's data. From 100,000 to 250,000 kg/cm^2 , the drop in electrical resistance is 12.9 per cent for Pb, 14.2 per cent for Sn, and 10.7 per cent for Cd. No jumps were observed in the electrical resistance of Wood's alloy.

11,361 PHASE TRANSITION IN MERCURY TELLURIDE by J. Blair and A. C. Smith (MIT); *Phys. Rev. Lett.*, Vol. 7, pp. 124-125 (L), Aug. 15, 1961

Measurements of the resistivity of HgTe using a four-probe method with a precision potentiometer are reported. Values of the resistivity are plotted as a function of pressure at room temperature. At 16,000 kg/cm^2 the resistivity increased, very slowly, by a factor of 10^4 to 10^5 . On decrease of the pressure the reverse process occurred, although the resistivity did not quite return to its original value. Several cracks were observed which could be due to strains arising from the misorientation of crystallites. Change in resistivity below the transition pressure is essentially the same for different ingots.

11,362 INTERBAND SCATTERING IN N-TYPE GERMANIUM by M. I. Nathan, W. Paul, and H. Brooks (Harvard U.); *Phys. Rev.*, Vol. 124, pp. 391-407, Oct. 15, 1961

Measurements of the pressure dependence of the electrical conductivity of n-type Ge to pressures of 30,000 kg/cm^2 at temperatures between 273° and 350°K are reported. A

satisfactory explanation of the results requires the existence of two different types of minima in the conduction band, separated by between 0.15 and 0.21 eV at 350°K with the lower range of values slightly preferred. The higher energy minima lie in the [100] direction in reciprocal space, and are similar in properties to the lowest set of minima in silicon. The changes in position of the two minima with pressure are determined. For the minima that are lowest at atmospheric pressure, $d(E_{111} - E_v)/dP = (4.9 \pm 0.5) \times 10^{-6} \text{ eV/kg-cm}^{-2}$, and for the [100] set, $d(E_{100} - E_v)/dP = (0.1 \pm 0.1) \times 10^{-6} \text{ eV/kg-cm}^{-2}$. The change in average is explained in terms of a sharing of electrons between states in the two sets of minima, and an additional relaxation process that scatters carriers from one type of minimum into the other. The effect of pressure on the effective masses, elastic constants, and the deformation potential is briefly considered.

11,363 ON THE QUESTION OF THE INFLUENCE OF IMPURITIES ON THE ELECTRICAL CONDUCTIVITY AND ABSORPTION SPECTRA OF ALKALI-HALIDE CRYSTALS [in Russian] by E. K. Zavadovskaia, M. N. Treskina, and I. Ia. Melik-gaikazian (Tomsk Polytech. Inst.); *Izv. VUZ, Fizika*, No. 2, pp. 60-65, 1961

Investigations of the influence of the impurity distribution of lead in NaCl and KCl crystals on the magnitude of the electrical conductivity, as one of the most structurally-responsive properties of insulating crystals, are reported. The relation between the change in the electrical conductivity and the magnitude of the absorption coefficient at the maximum of additional absorption for $\lambda = 273 \text{ m}\mu$ is established for KCl-PbCl₂ and NaCl-PbCl₂ crystals. It is shown that only that part of the impurity which enters into the site of the crystal lattice exerts substantial influence on the electrical conductivity of the crystals.

11,364 INFLUENCE OF SILVER IMPURITIES ON THE ANNEALING KINETICS OF QUENCHED GOLD SPECIMENS by F. Cattaneo and E. Germagnoli (Lab. Cent. Info.); *Phys. Rev.*, Vol. 124, pp. 414-419, Oct. 15, 1961

The recovery of quenched-in extra resistivity in thin Au wires to which atomic concentrations of As equal to 1.2×10^{-3} or 1.4×10^{-4} have been added is discussed. Recovery occurs at higher temperatures than for pure specimens, the effective activation energy being larger than 1 eV. The interpretation is that vacancy-impurity complexes with a binding energy of about 0.3 eV are formed. Evidence of motion of defects at low temperature is also obtained in the case of impure specimens.

11,365 INVESTIGATION OF THE ELECTRICAL CONTACT PROPERTIES OF GRANULAR CARBON AGGREGATES by E. D. Macklen (Stand. Telecommun. Lab.); *Brit. J. Appl. Phys.*, Vol. 12, pp. 443-446, Sept. 1961

An investigation of the heat treatment of granular carbon aggregates in various ambient gases is reported. In inert gases (hydrogen, nitrogen, argon, etc.) and in vacuo, either a constant or a decreasing electrical resistance was observed for increasing heat treatment temperature. Ambient gases containing either free or combined oxygen produced a sharp resistance maximum at about 530°C. The increase in resistance is attributed to the formation of a nonconducting surface oxide layer which decomposes when the heat treatment temperature is increased.

11,366 CERTAIN PROPERTIES OF SOLID SOLUTIONS OF THE KCl-KBr SYSTEM IN CONNECTION WITH THEIR IMPERFECTION [in Russian] by M. N. Treskina and E. K. Zavadovskaia (Tomsk Polytech. Inst.); *Izv. VUZ Fizika*, No. 2, pp. 55-59, 1961

The influence of the composition of solid solutions of the KCl-KBr system on their ionic conductivity, molecular concentration, vacancy concentration, F-band half-width, coefficient of linear expansion, melting point and microhardness is considered. It is found that all these properties except microhardness tend strongly toward degradation compared with pure KCl and KBr single-crystals, when small additions of KCl are inserted in KBr. This is attributed to Schottky imperfections. An attempt is made to determine the influence of dislocations on the magnitude of the ionic conductivity and microhardness of crystals of the given system.

11,367 DEPENDENCE OF THERMO-STIMULATED CURRENT CURVES ON HEATING RATE by C. G. Clayton, J. B. Whitaker, G. A. Briggs, and T. G. Kelly (Atomic Energy Res. Estab.); *Nature*, Vol. 192, pp. 349-350 (L), Oct. 28, 1961

Two models which explain the heating-rate sensitive secondary peak observed in thermo-stimulated currents in irradiated CdS single crystals are discussed. The irradiation was carried out at 90°K with Co⁶⁰ γ radiation. In one model it is assumed that electrons are held in traps of increasing depth and that the escape frequency factor increases with trap depth. At high and low heating rates, the electrons are released into the conduction band in turn from these levels to give a broad thermo-stimulated peak. For particular values of trap depths and escape frequency factors, a high degree of simultaneous release occurs over a narrow heating rate range, resulting in the peak. In the other model, the electrons associated with the secondary peak are assumed to be held in traps at a level E_1 and are released either directly into the conduction band or indirectly through a second shallower level E_2 . At a low heating rate, the secondary peak does not appear since the electrons are all released indirectly through E_2 . At some higher heating rate the electrons are released directly into the conduction band, producing the observed peak. To account for the disappearance of the peak at the higher heating rates, a hole trap is introduced and E_1 is also assumed to act as a recombination center.

11,368 PRE-THERMAL BREAKDOWN PROCESSES. I. INHOMOGENEOUS CURRENT DENSITY DISTRIBUTION AT HIGH ELECTRIC LOADS IN CdS SINGLE CRYSTALS [in German] by K. W. Böer, H. J. Hänsch, U. Kümmel, H. Lange, and E. Nebauer (Humboldt U.-Germ. Acad. Sci.); *Phys. Status Solidi*, Vol. 1, No. 2, pp. 169-180, 1961

An electro-thermo-optical method for measuring the distribution of current density within crystals is described. The method has been used for determining the distribution of high current densities in CdS single crystals. Relations between temperature distributions, current density distributions, and the current-voltage characteristics are discussed.

11,369 ELECTRICAL PROPERTIES OF GERMANIUM-SILICON ALLOYS by A. Levitas (Sylvania); *Phys. Rev.*, Vol. 99, p. 1810, 1955

Resistivity and Hall coefficient measurements made on homogeneous Ge-Si alloys over a temperature range 77° to 800°K are reported. Pure polycrystalline samples were used for almost all points. P-type material was used for the Hall measurements, which were in the temperature range 77° to 300°K with

CONDUCTIVITY (Cont'd)

a magnetic field of 1300 gauss. An attempt is made to correlate these data with assumed random lattice substitutions, and previous energy gap data for these alloys.

11,370 ELECTRICAL PROPERTIES OF PURE TELLURIUM AND TELLURIUM-SELENIUM ALLOYS by A. Nussbaum (U. Pennsylvania); *Phys. Rev.*, Vol. 94, pp. 337-342, 1954

Resistivity and Hall coefficient measurements made on single crystal Te and Te-Se alloy samples are reported. Alloys of 2.7 to 13.2 per cent Se were used, and the temperature was varied from liquid helium to 550°K. The alloys show a double reversal in the sign of the Hall coefficient as does pure Te. The room temperature resistivity and lower Hall reversal point both change with Se concentration. With increasing Se concentrations the energy gap increases and the upper Hall reversal temperature decreases. An hypothesis explaining these data is given.

11,371 SOME PROPERTIES OF In_2Te_3 AND Ga_2Te_3 , by J. C. Woolley and B. R. Pamplin (U. Nottingham); *J. Electrochem. Soc.*, Vol. 108, pp. 874-879, Sept. 1961

Measurements of the coefficient of thermal expansion, electrical conductivity and Hall effect of Ga_2Te_3 and In_2Te_3 are reported. The determination of activation energy values from the electrical measurements and their relation to the energy gap are discussed and values of activation energies and also of electron mobilities are given for ordered and disordered In_2Te_3 . It is shown that the change in activation energy in In_2Te_3 at 470°C is not associated with a change in structure, and an explanation in terms of change in conduction band minimum is proposed. Results of preliminary room temperature measurements of thermal conductivity in Ga_2Te_3 and ordered In_2Te_3 are also given.

11,372 INVESTIGATION OF CERTAIN PHYSICAL PROPERTIES OF POLYCRYSTALLINE GaAs [in Russian] by M. A. Krivov, E. V. Malisova, V. A. Presnov, and V. F. Synorov (FTI, Tomsk U.); *Izv. VUZ, Fizika*, No. 2, pp. 66-70, 1961

Measurements of the specific resistivity, thermal EMF and Hall coefficient of polycrystalline gallium arsenide samples produced by sixfold zone refining of the synthesized material are presented. The measurements have been made by the usual method in the 173°-500°K temperature range. The presence of carrier degeneration and of impurity compensation is reported. A comparison has also been made between certain surface properties of gallium arsenide and germanium under different surface treatments.

11,373 SOME ELECTRICAL PROPERTIES OF SOLID SOLUTIONS HgTe-HgSe, HgTe- βHgS , HgSe- βHgS [in Russian] by I. I. Nikolskaya and A. R. Regel' (USSR Acad. Sci.); *Zhurn. Tek. Fiz.*, Vol. 25, pp. 1352-1356, 1955

Measurements of the electric conductivity and its temperature dependence, the thermoelectromotive force, and the Hall effect of the systems HgTe-HgSe, HgTe- βHgS , HgSe- βHgS are reported. The influence of a magnetic field on the electric conductivity and Hall constant is also discussed. The preparation of the specimens and the methods of measurement are described. Graphs depicting the relations are also presented. The influence of various factors, including the ratio of components, the temperature, the magnetic field, and the technology of preparation is discussed, the results are compared, and theoretical conclusions are given. The specific electric

properties of the system HgTe-HgSe are related to the presence of carriers of both signs, but the data are not sufficient to make a complete quantitative analysis.

11,374 PROPERTIES AND STRUCTURE OF TERNARY SEMI-CONDUCTING SYSTEMS: ELECTRICAL PROPERTIES AND STRUCTURE OF SOME MATERIALS IN THE SYSTEM TI-Sb-Se [in Russian] by B. T. Kolomiets and N. A. Goryunova (USSR Acad. Sci.); *Zhurn. Tek. Fiz.*, Vol. 25, No. 6, pp. 984-994, 1955

The results of an investigation of the structure and electrical properties of some materials in the system TI-Sb-Se are given. All the compositions of the system $\text{TI}_2\text{Se-Sb}_2\text{Se}_3$ have been obtained by alloying their components. The preparation of the specimen is described. In the pseudo-binary cut $m\text{TI}_2\text{Se} \cdot n\text{Sb}_2\text{Se}_3$ of the ternary system TI-Sb-Se a chemical compound $\text{TI}_2\text{Sb}_2\text{Se}_4$ appears which has the properties of a p-type semiconductor with conductivity $10^{-4} \text{ ohm}^{-1} \text{ cm}^{-1}$ in room temperature and a photoconductivity with a maximum at $x = 1.4\mu$. Varying the proportion of the components in the series $m\text{TISe} \cdot n\text{Sb}_2\text{Se}_3$ it is possible to obtain a variety of materials with conductivities ranging over six orders of magnitude and with spectral distribution containing peaks between 0.8 - 1.4μ . The interchange As for Sb gives rise to a new group of semiconductors having an amorphous structure. Introduction of Te increases the conductivity up to $10^{-3} \text{ ohm}^{-1} \text{ cm}^{-1}$, not affecting the amorphous structure. Introductory data on materials of the system $\text{TI}_2\text{Se} \cdot \text{As}_2(\text{Se, Te})_3$ are included.

11,375 PROPERTIES AND STRUCTURE OF TERNARY SEMI-CONDUCTIVE SYSTEMS. III. CONDUCTIVITY AND PHOTOCONDUCTIVITY IN SYSTEMS OF SULFIDES OF THALLIUM, ANTIMONY, AND BISMUTH by N. A. Goryunova, B. T. Kolomiets, and A. A. Malkova (Leningrad Phys. Tech. Inst.); *Soviet Phys.-Tech. Phys.*, Vol. 1, pp. 1583-1590, Aug. 1957

An investigation of the structure and photoconductivity of alloys in the systems $\text{TI}_2\text{S-Sb}_2\text{S}_3$ and $\text{Sb}_2\text{S}_3\text{-Bi}_2\text{S}_3$ is reported. All the alloys examined in the $\text{TI}_2\text{S-Sb}_2\text{S}_3$ system exhibited an exponential dependence of the conductivity on temperature. A ternary compound, $\text{TI}_2\text{S} \cdot 3\text{Sb}_2\text{S}_3$, was found to exist in the $\text{TI}_2\text{S-Sb}_2\text{S}_3$ system. All of the alloys investigated in the $\text{TI}_2\text{S-Sb}_2\text{S}_3$ system contained two phases. Both n-type and p-type alloys were found. In the $\text{Sb}_2\text{S}_3\text{-Bi}_2\text{S}_3$ system, there was a very sharp decrease in photoconductivity when relatively small quantities of Sb_2S_3 were added to Bi_2S_3 . All alloys in the system $\text{Sb}_2\text{S}_3\text{-Bi}_2\text{S}_3$ exhibited an exponential temperature dependence of conductivity. A series of substitutional solid solutions was found in the $\text{Bi}_2\text{S}_3\text{-Sb}_2\text{S}_3$ system. Excess sulfur has a pronounced effect on the spectral sensitivity and the photoconductivity of alloys in the $\text{Bi}_2\text{S}_3\text{-Sb}_2\text{S}_3$ system.

11,376 PROPERTIES AND STRUCTURE OF TERNARY SEMI-CONDUCTOR SYSTEMS. IV. ELECTRICAL AND PHOTO-ELECTRICAL PROPERTIES OF SUBSTITUTIONAL SOLID SOLUTIONS IN THE ZnTe-CdTe SYSTEM by B. T. Kolomiets and A. A. Malkova (USSR Acad. Sci.); *Soviet Phys.-Tech. Phys.*, Vol. 3, pp. 1532-1538, 1958

Measurement of conductivity and photoconductivity with varying temperature for seven different alloys of ZnTe and CdTe are discussed. The data indicate that the electrical properties tend to be linearly dependent on alloy concentration ratio.

CONDUCTIVITY (Cont'd)

11,377 ELECTRICAL CONDUCTIVITY OF MIXED CRYSTALS WITH METALLIC BONDS [in German] by G. Busch and U. Winkler (Eth, Zurich); *Helv. Phys. Acta*, Vol. 24, pp. 578-583, 1953

An investigation of the electrical conductivity of the ternary system Mg-Ge-Sn with the mixed crystal formula $Mg_2(Ge_ySn_{1-y})$ is reported. Lattice constants of the ternary system $Mg_2Ge_ySn_{1-y}$ as a function of the proportion between Mg_2Ge and Mg_2Sn are given. Results of the measurements of the electrical conductivity of the system $Mg_2Ge_ySn_{1-y}$ as a function of absolute temperature and of the proportion of mixed crystals are presented. The law of electrical conductivity for the ternary system is derived and the activation energy ΔE_σ is calculated and plotted as a function of the proportion of mixed crystals y . A table of the experimental results is given.

11,378 ELECTRICAL RESISTIVITY OF CUBIC SODIUM TUNGSTEN BRONZE by L. D. Ellerbeck (U. Omaha), and H. R. Shanks, P. H. Sidles, G. C. Danielson (Iowa State U.); *J. Chem. Phys.*, Vol. 35, pp. 298-302, July 1961

Electrical resistivities of the nonstoichiometric compounds Na_xWO_3 measured as a function of Na concentration from $x = 0.48$ to $x = 0.88$, and as a function of temperature from $T = 4^\circ K$ to $T = 873^\circ K$ are reported. The minimum in electrical resistivity near $x = 0.75$, which has been reported by earlier investigators, is absent in single crystals which were selected to be electrically homogeneous. Above room temperature the electrical conductivity increases approximately linearly with Na concentration; at liquid-helium temperatures the electrical conductivity increases approximately as the fourth power of Na concentration. The method of preparation and selection of samples is described. Electrical resistivity measurements were made throughout the temperature range by means of a standard potential-drop technique.

Resistivity of MnHg - See 11,411

Anisotropic Conductivity in CdSb - See 11,436

Conductivity of Tl-Sb-Se Compounds - See 11,374

SUPERCONDUCTIVITY

11,379 THEORY OF MANY-PARTICLE SYSTEMS II. SUPERCONDUCTIVITY by L. P. Kadanoff and P. C. Martin (Harvard U.); *Phys. Rev.*, Vol. 124, pp. 670-697, Nov. 1, 1961

A fermion system with a simple attractive interaction is discussed with the aid of time-dependent correlation functions. Although perturbation theory is inapplicable, a sequence of previously-described correlation approximations can be employed. The lowest approximation in the sequence expresses the two-particle correlation function in terms of single particle functions and leads to the Hartree approximation; the second expresses the three particle correlation function in terms of one- and two-particle correlation functions and leads to the time-dependent correlation functions that characterize the superconducting model of Bardeen, Cooper, and Schrieffer. These correlation functions are determined and the thermodynamic properties of the superconductor are calculated from them.

The electromagnetic effects of the superconductor predicted by the Bardeen-Cooper-Schrieffer time-dependent correlation functions and the properties of a pure superconductor which depend on the lifetimes of the single-particle excitations are also considered.

11,380 ELEMENTARY DERIVATION OF THE ELECTRON-ELECTRON INTERACTION VIA THE PHONON FIELD by R. N. Hill (Yale U.); *Am. J. Phys.*, Vol. 29, pp. 739-740, Nov. 1961

The electron-electron interaction via the phonon field is calculated from classical physics. A transition to quantum mechanics via the correspondence principle then yields the matrix element which is the starting point of the Bardeen-Cooper-Schrieffer theory of superconductivity.

11,381 QUANTIZATION OF FLUX IN A SUPERCONDUCTING CYLINDER by J. Bardeen (U. Illinois); *Phys. Rev. Lett.*, Vol. 7, pp. 162-163 (L), Sept. 1, 1961

A discussion of the flux quantization units in a superconducting cylinder is presented. An appropriate periodic solution to the Ginzburg-Landau equation is derived for imposing the boundary conditions of a cylindrical tube having a thin film of thickness $d < 2\lambda$ (λ = penetration depth). In superconducting tubes of very small diameter and with wall thickness of the order of the penetration depth, the quantum flux depends on the dimensions of the tube and may be appreciably less than $hc/2e$.

11,382 QUANTIZATION OF THE FLUXOID IN SUPERCONDUCTIVITY by J. B. Keller and B. Zumino (NYU); *Phys. Rev. Lett.*, Vol. 7, pp. 164-165 (L), Sept. 1, 1961

A theoretical discussion of the quantization units of the fluxoid in superconductivity is presented. It is shown that in a superconductor the fluxoid is always quantized in multiples of the natural unit ($\pi\hbar c/e$) even though the flux may be quantized in smaller units. Bardeen's result is deduced by considering a thin cylindrical tube of radius r and thickness $d \leq \lambda$ (λ = penetration depth) and is shown to be consistent with the Fluxoid Quantization Theory.

11,383 ENHANCEMENT OF SUPERCONDUCTIVITY BY EXTRACTION OF NORMAL CARRIERS by R. H. Parmenter (RCA Labs.); *Phys. Rev. Lett.*, Vol. 7, pp. 274-277 (L), Oct. 1, 1961

A nonmagnetic method for raising or lowering the transition temperature of a superconducting film is discussed. The film is sandwiched between superconductor contacts, with insulating layers between the superconductors. By applying a bias between the two contacts equal to or greater than the energy gap difference of the two superconductors (film = A, contacts = B) $2(\epsilon_{OB} - \epsilon_{OA})$, both normal holes and normal electrons can be extracted from the film. If the bias is made greater than the energy gap sum $2(\epsilon_{OB} + \epsilon_{OA})$, both normal carriers are injected into the film. The extraction of normal carriers causes a rise in the transition temperature of the film. The transition temperature is lowered by the injection of normal carriers. It is suggested that a normal film can be made superconducting by extracting normal carriers from the film, with the operating temperature less than T_{cB} but greater than T_{cA} (the usual transition temperature of the film).

11,384 MAGNETIC FIELD DEPENDENCE OF THE SUPERCONDUCTING PENETRATION DEPTH IN THIN SPECIMENS by

SUPERCONDUCTIVITY (Cont'd)

D. H. Douglass, Jr. (Lincoln Lab.); Phys. Rev., Vol. 124, pp. 735-739, Nov. 1, 1961

The magnetic field dependence of the superconducting penetration depth for very thin films as predicted by the Ginzburg-Landau theory is considered. The results obtained depend upon the boundary conditions on the film. For the usual case of equal magnetic fields on opposite sides of the film, the penetration depth increases smoothly toward infinity as the critical field is approached, corresponding to a second-order phase transition. For the less common case of unequal fields on opposite sides, the penetration depth increases toward a finite value as the critical field is approached, corresponding to a first-order phase transition. The results for the latter case are shown to agree remarkably well with the very precise experiments of Garwin, Erlbach, and Sarachik on the field dependence of the penetration of a 250 Å film of Pb. The penetration depth in zero field as a function of thickness is also considered.

11,385 SUPERCONDUCTIVITY OF SUPERIMPOSED METALS by A. C. Rose-Innes and B. Serin (Rutgers U.); Phys. Rev. Lett., Vol. 7, pp. 278-279 (L), Oct. 1, 1961

Measurements of the transition temperature in thin films of superconducting tin evaporated on gold substrates are reported. It was found that there was a rapid decrease in transition temperature when the thickness of tin was less than about 7000 Å. Films with transition temperatures close to the value of bulk tin had sharply defined critical magnetic fields, and the magnetization and critical fields exhibited the behavior of an ideal superconductor. Films with appreciably lower transition temperatures exhibited characteristics of nonideal superconductors. Experiments have shown that these results can be explained by diffusion which takes place even though the substrate is cooled during the evaporation. The thickness of the film then does not determine the properties of the film. Several mechanisms by which the diffusion can lower the transition temperature are discussed.

11,386 SUPERCONDUCTIVITY OF NIOBIUM-MOLYBDENUM ALLOYS BELOW 1°K by J. K. Hulm and R. D. Blaugher (Westinghouse Res. Labs.), and T. H. Geballe and B. T. Matthias (Bell Labs.); Phys. Rev. Lett., Vol. 7, pp. 301-303 (L), Oct. 15, 1961

The variation of the superconductivity transition temperature with composition in the Nb-Mo system below 1°K is discussed. A linear dependence of T_c on composition was found. This is in disagreement with the Bardeen-Cooper-Schrieffer theory. For the BCS theory to agree with the experimental results, a large variation in V , the (positive) interaction potential giving rise to the superconducting state, must be assumed. This, however, does not agree with the fact that T_c is a simple function of $N(0)$, the density of states at the Fermi surface, alone throughout the periodic system.

MAGNETOELECTRIC (GALVANOMAGNETIC) PROPERTIES

11,387 QUANTUM THEORY OF GALVANOMAGNETIC PHENOMENA by E. N. Adams and T. D. Holstein (Westinghouse); J. Phys. Chem. Solids, Vol. 10, pp. 254-276, Aug. 1959

A quantum theory of electrical conduction in crossed electric

and magnetic fields, considered for the limit of very weak scattering, is presented. A density matrix formulation of this problem is used and an arbitrary scattering mechanism is considered. The theory is found to be completely equivalent to earlier theories of Titeica and Davydov and Pomeranchuk. Formulae for the resistivity in the quantum limit for both longitudinal and transverse orientations of the electric field, for degenerate and non-degenerate statistics, and for several different scattering mechanisms are given. The oscillatory conductivity for acoustical and ionized impurity scattering mechanisms is calculated. Formulae obtained for the quantum transport effects are in disagreement with the formulae of Lifshitz and Argyres. The discrepancy is attributed to unwarranted approximations in their treatments of scattering.

11,388 ANGULAR DEPENDENCE OF MAGNETORESISTANCE IN HgSe by T. C. Harman (MIT); J. Appl. Phys., Vol. 32, pp. 1800-1801 (L), Sept. 1961

An experimental investigation of the angular dependence of magnetoresistance in HgSe is reported. Oriented parallelepiped-shaped specimens of HgSe were cut from a single-crystal ingot, and annealed. Before etching, measurement yielded a negative longitudinal magnetoresistance not reproducible in magnitude, while after etching negative effects disappeared and results were reproducible. The ends of the samples were ultrasonically soldered with In and Cu leads attached to the In. For transverse magnetoresistance, magnetic field, electric current and probe wires were oriented in mutually perpendicular directions. Magnetoresistance was measured as a function of the angle between current and field at 78°K. There was a maximum at 90° and the values approached zero at 0° and 180°. The results are consistent with a model involving a nearly spherically symmetrical conduction band.

11,389 TRANSVERSE MAGNETORESISTANCE OF GERMANIUM IN THE QUANTUM LIMIT by T. J. Diesel and W. F. Love (U. Colorado); Phys. Rev., Vol. 124, pp. 666-668, Nov. 1, 1961

Measurements of the transverse magnetoresistance of very pure single crystal n-type germanium as a function of temperature and magnetic field in pulsed fields up to 194 kgauss, and in the temperature range from 11°K to 78°K are reported. The results below 20°K are obscured by hot electron effects and non-ohmic behavior of the crystal, but in the quantum limit and above, the magnetoresistance ratio varies linearly with magnetic field above 40 kgauss and has a T^{-1} temperature dependence. The results of these experiments do not agree with theoretical predictions for various scattering mechanisms.

Hall Voltage of a Semiconductor Rotating in a Magnetic Field - See 11,355

Hall Constant of GaAs - See 11,359 and 11,372

Hall Effect in Solid Solutions of HgTe-HgSe, HgTe-HgS, and HgSe-HgS - See 11,373

11,390 CYCLOTRON RESONANCE IN COPPER by A. F. Kip, D. N. Langenberg, and T. W. Moore (U. California); Phys. Rev., Vol. 124, pp. 359-372, Oct. 15, 1961

Extensive cyclotron resonance experiments in Cu at 24 kMc are described. The results are consistent with the Azbel'-Kaner theory of cyclotron resonance in metals and with known Fermi surface geometry. "Stationary" orbits (orbits having extremal effective mass and vanishing average velocity in the magnetic field direction) are found to dominate the cyclotron resonance

MAGNETOELECTRIC (GALVANOMAGNETIC) PROPERTIES (Cont'd)

signals in Cu. The effective mass anisotropy of various classes of stationary orbits is reported. The effects of tipping the magnetic field slightly out of the plane of the sample surface and of the direction of the rf currents with respect to the magnetic field are described.

Cyclotron Resonance in Deformed InSb, Ge and Si Crystals - See 11,420

11,391 GALVANOMAGNETIC COEFFICIENTS OF SINGLE-CRYSTAL TELLURIUM by A. Nussbaum and R. J. Hager (Honeywell Res. Ctr.); Phys. Rev., Vol. 123, pp. 1958-1964, Sept. 15, 1961

Measurements of the twelve galvanomagnetic coefficients of Te crystals grown by the Czochralski method over the temperature range 77° - 300° K are reported. The results of these measurements plus previous measurements at 4.2° K and a determination of the effect of pressure on one of the Hall coefficients are combined with symmetry characteristics to postulate an energy band structure. This structure differs from those previously proposed on the basis of tight-binding methods or by simple applications of group theory.

ELECTRICAL PROPERTIES OF SURFACES

11,392 THE STUDY OF SURFACE PHENOMENA IN SEMICONDUCTORS BY THE FIELD EFFECT TECHNIQUE [in French] by R. Pick and M. Savelli (U. Algeria); J. Phys. Radium, Vol. 21, pp. 743-750, Oct. 1960

An investigation of surface phenomena by the field effect technique, with the limitations of the technique taken into consideration, is presented. Although the field effect method causes the density of free carriers in the surface to be different from that in bulk, the conditions of thermodynamic micro-equilibrium were satisfied; thus the use of the Shockley-Read recombination theory is validated. From measurements of conductivity variations and photoconductivity decrease in relation to the field effect, the determination of the density of superficial recombination centers, their energy levels and the capture probabilities of electrons or holes by these centers is obtainable.

11,393 THERMIONIC EMISSION OF UC-Nb by R. H. Abrams, Jr. and F. E. Jamerson (Genl. Motors); J. Appl. Phys., Vol. 32, pp. 1783-1784 (L), Sept. 1961

Measurements of the thermionic constants and spectral emissivity of a UC (80 per cent by volume)-Nb (20 per cent by volume) disc are reported. The sample was prepared by compressing a powder mix of UC and Nb under helium gas pressure of 680 atmospheres at 1970° K. Spectral emissivity was found by comparing optical pyrometer readings of the surface and a hohlraum, assuming the surface and interior of the disc to be at the same temperature. The UC-Nb served as an electron bombardment cathode for the emission experiment. Data were recorded over the temperature range 1380° - 1960° K for field strengths up to 23,000 v/cm. Schottky temperatures were lower than observed temperatures, indicating field strength limitations. Saturated current values (which may be conservative) were obtained by passing a line with an observed temperature slope through highest data points.

11,394 THERMIONIC EMISSION FROM A TANTALUM CRYSTAL IN CESIUM OR RUBIDIUM VAPOR by H. F. Webster (GE); J. Appl. Phys., pp. 1802-1803 (L), Sept. 1961

Measurements of the thermionic emission from a hemispherical tantalum crystal which had its work function altered by an adsorbed layer of alkali metal are reported. The experimental method was similar to that of Martin for tungsten, but was modified to permit quantitative measurements of emission current densities from four different crystal faces to be made by a moving pinhole and a Faraday cage. The Ta cathode was made by heating the lower end of a polycrystalline Ta rod by electron bombardment. The emission density is strongly dependent on the crystallographic orientation of the Ta, and the emission pattern changes are different for Cs and Rb vapors.

11,395 ANOMALOUS SKIN EFFECT IN BISMUTH by G. E. Smith (U. Chicago); Phys. Rev., Vol. 115, pp. 1561-1568, Sept. 15, 1959

High-frequency (23.5-kMc) surface resistance measurements made on plane surfaces of single-crystal bismuth at 2° K as a function of orientation are reported. Extreme anomalous skin effect conditions prevail, allowing details of the Fermi surface to be deduced from Pippard's theory. In Shoenberg's model of the electron band, components of the inverse effective-mass tensor divided by the Fermi energy are found to be $\alpha_1/E_F = 9.10$, $\alpha_2/E_F = 0.088$, $\alpha_3/E_F = 4.7$, and $\alpha_4/E_F = 0.38$ (in units of $10^3/\text{ev}$). These results are in essential agreement with values obtained from de Haas-van Alphen experiments and cyclotron resonance. The number of ellipses is definitely established to be six and the number of electrons to be $N = 5.5 \times 10^{17}/\text{cm}^3$. The parameters for the two hole ellipsoids are found to be $\beta_1/E_F = \beta_2/E_F = 1.5$ and $\beta_3/E_F = 0.12$. Assuming Shoenberg's value $E_F = 0.0177$ ev, the value $E_h = 0.00112$ ev is calculated from specific heat data. The reflection of carriers from the surface of the sample is found to be predominantly specular in contrast to diffuse reflection found in other metals.

ELECTRICAL PROPERTIES OF SPECIFIC MATERIALS

11,396 ON THE ELECTRIC PROPERTIES OF MIXED CRYSTALS OF THE FORM $\text{In}(\text{As}_y\text{P}_{1-y})$ [in German] by H. Weiss (Siemens AG); Z. Naturforsch., Vol. 11a, No. 6, pp. 430-434, 1956

Measurements of the specific conductivity and Hall constant of crystals of the composition $\text{In}(\text{As}_y\text{P}_{1-y})$ are reported. For these mixed crystals the width of the forbidden energy band at absolute zero increases proportionally to the content of phosphorus. Simultaneously the electron and hole mobilities decrease while a high mobility ratio is preserved.

MAGNETIC PROPERTIES

FERRO- AND FERRIMAGNETISM

11,397 COMPOSITION AND THICKNESS EFFECTS ON MAGNETIC PROPERTIES OF ELECTRODEPOSITED NICKEL-IRON THIN FILMS by I. W. Wolfe (GE); J. Electrochem. Soc., Vol. 108, pp. 959-964, Oct. 1961

The effects of thickness and composition on the easy axis-disturb, the easy axis coercive force, and the anisotropy

field of electrodeposited Ni-Fe films are discussed. The measurements were made by hysteresigraph techniques. The experimental data indicate that a stress dependent effect influences wall motion and that an anisotropic stress mechanism can explain the anisotropy in the films.

11,398 EFFECT OF CHEMISORBED HYDROGEN ON THE MAGNETIZATION OF NICKEL by R. E. Dietz (Bell Labs.), and P. W. Selwood (Northwestern U.); J. Chem. Phys., Vol. 35, pp. 270-281, July 1961

The effect of chemisorbed hydrogen on the saturation magnetization of fine particles of Ni is discussed. For certain preparations the saturation moment of the Ni is within 1 or 2 per cent of that of bulk Ni; this is considered evidence that the surfaces of the Ni in the sample were substantially free from chemisorbed impurities, and that the electronic state of the Ni was identical to that of bulk Ni. For these preparations, hydrogen decreases the saturation moment of the Ni by about 1.7 Bohr magneton per average atom of hydrogen absorbed. The decrease is attributed to spin moment cancellation of the Ni 3d electrons by the hydrogen electron. The effect of chemisorbed hydrogen on the saturation magnetization of Ni appears to be independent of temperature up to 300°K. A brief discussion of experimental technique and sample preparation is given.

11,399 THE INFLUENCE OF INTERNAL STRESS ON THE COERCIVE FORCE OF THICK FILMS OF COBALT AND NICKEL ELECTRODEPOSITS by R. D. Fisher (Nat'l. Cash Register); Electrochem. Soc., Vol. 108, p. 173C (A), Aug. 1961

The influence of a metal salt (CoCl_2 or NiCl_2) and saccharin solution concentration on the average stress and microstructure of Ni and Co electrodeposits was discussed and measurements of the magnetic properties of the electrodeposits were presented. The coercive force and stress of the nickel and cobalt electrodeposits have been determined and compared at thickness values of approximately 5μ . The results indicate that in certain instances the coercive force of the deposits can be directly correlated with the residual stress.

Magnetic Properties of:

- Co Films - See 11,327
- Co-P Films - See 11,306
- Fe-Ni Films - See 11,307 and 11,471

11,400 APPLICATION OF THE PADÉ APPROXIMANT METHOD TO THE INVESTIGATION OF SOME MAGNETIC PROPERTIES OF THE ISING MODEL by G. A. Baker, Jr. (U. California); Phys. Rev., Vol. 124, pp. 768-774, Nov. 1, 1961

The reduced magnetic susceptibility and spontaneous magnetization are found using the Padé approximant method from the exact series expansions for the Ising model. Values of susceptibility and magnetization for the face-centered cubic, body-centered cubic, simple cubic, triangular, simple quadratic andoneycomb lattices are given.

11,401 EXPERIMENTAL TEST OF THE SPIN-WAVE THEORY OF FERROMAGNET by A. C. Grossaro, V. Jaccarino, and J. P.emeika (Bell Labs.); Phys. Rev. Lett., Vol. 7, pp. 122-124, Aug. 15, 1961

An experimental test of Bloch's theory of the thermodynamic properties of an idealized model of a ferromagnet is reported.

A precise determination of the temperature dependence of magnetization of CrBr_3 , which satisfies the assumptions of the model closely, has been made using nuclear magnetic resonance (NMR) techniques. The Cr^{53} NMR was searched for in the frequency region below 85 Mc/sec using a frequency-swept modified Robinson marginal oscillator. The spectrum obtained at 58.038 Mc/sec, 1.34°K, in zero external field showed three distinct absorptions. Temperature dependence of the Cr^{53} NMR is plotted. These results are then applied to a discussion of the spin-wave theory.

11,402 SUSCEPTIBILITY OF GADOLINIUM IRON GARNET BELOW THE NÉEL POINT by W. P. Wolf (Clarendon Lab.) and R. M. Bozorth (Bell Labs.); Phys. Rev., Vol. 124, pp. 449-452, Oct. 15, 1961

Measurements of the spontaneous magnetization and the superposed paramagnetic susceptibility of gadolinium iron garnet made with a specimen of good stoichiometry in the range of 2° to 300°K are reported. It is concluded that the effective field which the Fe sublattices exert on the Gd ions causes paramagnetic saturation and consequently a reduction in susceptibility of the Gd sublattice. Good quantitative agreement is obtained by using molecular field theory without any adjustable constants. In contrast to earlier interpretations, it is not found necessary to postulate appreciable antiferromagnetic interactions between the Gd ions.

Magnetic Susceptibility of the Systems HgTe-HgSe , $\text{HgTe-}\beta\text{HgS}$, $\text{HgSe-}\beta\text{HgS}$ - See 11,272

Permeability of Magnetic Cores - See 11,519 and 11,520

Mn-Zn Ferrites with Temperature Independent Permeability - See 11,314

Ni-Zn Ferrites with High Initial Permeability and Low Hysteresis Loss - See 11,315

11,403 TEMPERATURE DEPENDENCE OF MAGNETIC LOSSES by J. J. Gniewek and R. L. Powell (Nat'l. Bu. Stand.); Prog. Cryogenic Engrg. Conf., p. 33 (A), Aug. 1961

Measurements of total magnetic losses for a variety of commercial magnetic materials at 4°, 76°, 195°, and 273°K in the frequency range 20 to 1000 cps were reported. Materials tested included 1-4 per cent Si-Fe and 48 per cent Ni-Fe alloys. The levels of peak induction vary from two kgauss to the maximum obtainable while still maintaining a sinusoidal voltage wave form with less than 5 per cent distortion. The total losses were separated into hysteresis and eddy current losses. The temperature dependence of the eddy current losses was compared with that predicted by classical theory using experimentally measured values of resistivity. Factors affecting the temperature variation of hysteresis loss were discussed, the predictions of the theory being applied to the experimental data. In general, it is found that the eddy current losses may be predicted with reasonable accuracy from the temperature dependence of the material resistivity. The behavior of the hysteresis loss is, however, more complicated and predictions of its temperature dependence are less reliable.

11,404 ANGULAR DEPENDENCE OF TORQUE IN ANISOTROPIC PERMALLOY FILMS by W. D. Doyle, J. E. Rudisill, and S. Shtrikman (Franklin Inst.); J. Appl. Phys., Vol. 32, pp. 1785-1787 (L), Sept. 1961

A study of torque curves in a 1500°A, 77 per cent Ni film using a high-sensitivity (10^{-3} a-cm) continuous recording torque

magnetometer is reported. The torque curves are plotted and the anisotropy constant and rotational hysteresis loss per unit volume are computed. The experimental results are compared with three theories of the magnetization process in ferromagnets: coherent rotations of Stoner and Wohlfarth, 180° wall motion of Kandorsky, and an adaptation of the results of Shtrikman and Treves. In the reversible parts of the torque curves agreement is good with the first model, while the second model is good as long as the magnetization is parallel to the easy axis. The third model fits the data over the entire field range.

11,405 EQUIPMENT FOR THE DEPOSITION AND MEASUREMENT OF THE MAGNETIC ANISOTROPY OF THIN FILMS IN A HIGH VACUUM by V. Kamberský, Z. Málek, and J. Kaczér (Czech. Acad. Sci., Prague); Czech. J. Phys., Vol. 11B, pp. 369-372, 1961

Apparatus using the direct torque method for measuring magnetic anisotropy of thin ferromagnetic films in a high vacuum immediately after they have been deposited, without disturbing the vacuum, is described.

11,406 THE INFLUENCE OF PLASTIC DEFORMATION ON THE MAGNETOSTRICTION CONSTANT OF NICKEL by J. Paces and P. Suda (Czech. Acad. Sci., Prague); Czech. J. Phys., Vol. 11B, pp. 439-443, 1961

Measurements of the magnetostriction constant of nickel as a function of plastic deformation up to an elongation of 30 per cent are reported. The values of the magnetostriction constant in deformed samples deviate considerably, a fact which cannot be explained by errors of measurement. The absolute value of the magnetostriction constant decreases with increasing plastic deformation (by ~ 5 per cent).

Garnets with High Magnetic Moments - See 11,273 and 11,319

11,407 EXCITATION OF SPIN-WAVE RESONANCE BY MICROWAVE PHONONS by M. Pomerantz (IBM); Phys. Rev. Lett., Vol. 7, pp. 312-313 (L), Oct. 15, 1961

The interaction of phonons and magnons in thin ferromagnetic films is discussed. Experimental evidence is presented that in a film whose thickness is on the order of the magnon or phonon wave length, standing spin waves can be excited by phonons whose frequency equals that of the spin waves, but whose wave length is considerably larger than the magnon wave lengths. Experiments on Permalloy films near the composition 80 Ni 20 Fe have shown that the magnon-phonon interaction is strongly dependent on the magnetostriction of the films and that the resonance linewidths are approximately the same for all compositions studied. This indicates that the spin-phonon processes cannot be the major source of the linewidths and that there are more rapid processes shortening the lifetime of the spins.

11,408 LOW-TEMPERATURE FERROMAGNETIC RELAXATION IN YTTRIUM IRON GARNET by E. G. Spencer, R. C. LeCraw, and R. C. Linares, Jr. (Bell Labs.); Phys. Rev., Vol. 123, pp. 1937-1938, Sept. 15, 1961

Measurements of the ferromagnetic spin lattice relaxation time, τ_0 , from 4.2° to 300°K in single crystal yttrium iron garnet in which care was taken to reduce both the extraneous rare earth and ferrous impurity ions are reported. The measurements are

shown to be indicative of the purely ferric ion lattice at temperatures considerably lower than had previously been attained. The observations indicate that below approximately 150°K , τ_0^{-1} vs T is steeper than directly proportional to T , implying an extremely low value at 4.2°K . As a result of this, the nature of the ferric ion relaxation is more clearly defined over the low temperature region.

11,409 FERROMAGNETIC RESONANCE IN THIN COBALT FILMS by Z. Frait (Czech. Acad. Sci., Prague); Czech. J. Phys., Vol. 11B, pp. 360-368, 1961

Measurements on the ferromagnetic resonance of thin cobalt films, vacuum deposited on unheated glass, are discussed. The values of the g-factor, the width of the curve, the effective stress and uniaxial induced anisotropy have been determined as a function of the thickness of the film from measurements of the ferromagnetic absorption in a magnetic field normal and parallel to the surface of the film. Measurements were carried out at a frequency of 9200 Mc and on film thicknesses of 180 to 1800 Å. A qualitative explanation of the observed dependences is given.

Resonance Absorption of Microwaves in Ferrites - See 11,305

11,410 INFLUENCE OF MAGNON-PHONON COUPLING ON THE LOW-TEMPERATURE MAGNETIC PROPERTIES OF AN ANTI-FERROMAGNET by P. Pincus and J. Winter (U. California); Phys. Rev. Lett., Vol. 7, pp. 269-270 (L), Oct. 1, 1961

Theoretical relationships for the temperature dependence of the sublattice magnetization, parallel susceptibility, and nuclear relaxation rates of antiferromagnets are presented. The relations are based on the idea that the magnetostrictive terms in the Hamiltonian produce a magnon component in the thermal phonon spectrum, so that the phonons participate directly in the magnetic processes. Experimental results which agree with the derivations are presented.

11,411 ANTIFERROMAGNETISM OF MnHg by Y. Nakagawa and T. Hori (Gakushuin U.); J. Phys. Soc., Japan, Vol. 16, p. 1470 (L), July 1961

Experimental investigations of the magnetic susceptibility, the electrical resistivity and the crystal structure of MnHg in the temperature range from 90° to 360°K are reported. The magnetic susceptibility is independent of magnetic field up to 12 Koe. Above the Néel temperature, the susceptibility cannot be satisfactorily expressed by the Curie-Weiss law. The temperature dependence of the resistivity exhibits an anomaly at the Néel point. At low temperatures, MnHg is not transformed from cubic to tetragonal structure. It may be concluded that MnHg is antiferromagnetic at temperatures below 198°K .

11,412 ELECTRON PARAMAGNETIC RESONANCE AND ANTIFERROMAGNETISM IN LaCrO_3 by I. Weinberg and P. Larsen (Ford); Nature, Vol. 192, pp. 445-446 (L), Nov. 4, 1961

Electron paramagnetic absorption measurements performed in LaCrO_3 over the temperature range $200^\circ - 450^\circ\text{K}$ are discussed. The powder was prepared by heating reagent grade Cr_2O_3 and La_2O_3 at 1600°C for 2 hours. X-ray diffraction measurements indicated a typical perovskite structure with small distortions from cubic symmetry. The resonances were singly peaked, with g values equal to 1.98 at all observable temperatures. The line widths were found to exhibit the behavior predicted by Tsuya and Ichikawa, and the extinction of resonance below the transition indicates that impurities are not a major contribution

to line width. A Néel temperature $T_N \approx 295^\circ\text{K}$ was found. This agrees with previous magnetic susceptibility measurements but differs from the value of 320°K determined by neutron diffraction. The present results and those obtained by magnetic susceptibility techniques were obtained on material prepared in a similar manner.

11,413 ABSENCE OF ANTIFERROMAGNETIC DOMAIN WALLS IN MnF_2 by P. S. Pershan (Harvard U.); Phys. Rev. Lett., Vol. 7, pp. 280-281 (L), Oct. 1, 1961

Experiments which indicate the absence of antiferromagnetic domain walls in MnF_2 below the Néel point are discussed. The F^{19} nuclear resonance was measured in a single crystal with either an electric field applied in the [110] direction or a magnetic field applied in the [001] direction, or with both fields applied. A comparison of the signal obtained with the application of both electric and magnetic fields with that obtained with only an electric field indicated that there is only one domain. More than eighty per cent of the crystal was of the one domain type. It is suggested that domain walls in MnF_2 may be detected about 10°K below the Néel point.

11,414 ELECTRICALLY INDUCED SHIFT OF THE F^{19} RESONANCE FREQUENCY IN MnF_2 by P. S. Pershan and N. Bloembergen (Harvard U.); Phys. Rev. Lett., Vol. 7, No. 5, pp. 165-167 (L), Sept. 1, 1961

Experimental verification of the predicted linear effect of an applied electric field on the magnetic hyperfine interaction is presented. The work was conducted in antiferromagnetic MnF_2 . The absorption derivative of the F^{19} resonance in MnF_2 at 4.2°K in zero magnetic field is plotted for a variable electric field strength applied along the (100) crystallographic axis. The absorption derivative is compatible with a linear absolute shift $\Delta V_E = 5 \text{ kc}$ for each of the four F^{19} nuclei in the unit cell. The observed effect may be used to study the presence or absence of antiferromagnetic domain walls.

11,415 FERROMAGNETIC INTERACTION IN EuO by B. T. Matthias and R. M. Bozorth (Bell Labs.) and J. H. Von Fleck (Harvard U.); Phys. Rev. Lett., Vol. 7, pp. 160-161 (L), Sept. 1, 1961

The discovery of the first rare earth oxide to become ferromagnetic, EuO , is reported. It is found to have a Curie temperature of 77°K and a saturation moment of 7 Bohr magnetons. The existence of strong ferromagnetism in EuO at 77°K is used to explain the anomalous results previously obtained with EuR_2 . The Curie constant, $7.9N\beta^2/3k$, expected for an ^8S configuration, shows that the europium ion is divalent and isoelectronic with Gd^{++} . A plot of magnetization vs temperature in the ferromagnetic region shows EuO to have a high magnetic moment. It is proposed that the ferromagnetic exchange coupling is due to indirect exchange via excited states.

11,416 VISCOSITY AND HYSTERESIS PROPERTIES AT LOW TEMPERATURES OF MANGANESE IRON FERRITES CONTAINING COBALT ADMIXTURES by K. M. Bol'shova and T. A. Elkina (Moscow State U.); Soviet Phys.-JETP, Vol. 13, pp. 915-916, Nov. 1961

Measurements of the low temperature magnetic viscosity, magnetostriction, and hysteresis properties of a polycrystalline ferrite of composition $\text{Mn}_{1.75}\text{Co}_{0.05}\text{Fe}_{1.2}\text{O}_4$ are reported. An extremely high viscosity was found in the temperature region

from -100° to -150°C in static fields up to 250 oe. The remagnetization time was found to be of the order of tens of minutes to hours. It was found that in this temperature region Perminvar and rectangular loops are formed in oscillatory fields. The character of the variation in the form of the loop in increasing oscillatory fields is compared with the magnetic viscosity found in static fields.

PARAMAGNETISM

Paramagnetic Susceptibility of $\text{Gd}_3\text{Fe}_5\text{O}_{12}$ - See 11,402

11,417 HYPERFINE STRUCTURE OF DIVALENT AND TRIVALENT Fe^{57} IN COBALT OXIDE by G. K. Wertheim (Bell Labs.); Phys. Rev., Vol. 124, pp. 764-767, Nov. 1, 1961

The hyperfine structure of divalent and trivalent iron in CoO , obtained from the Mössbauer effect of Fe^{57} produced by the electron-capture decay of Co^{57} , is discussed. The two valence states are obtained respectively by x-ray and Auger effect de-excitation of the k-shell hole resulting from electron capture in divalent Co^{57} . Higher valence states which could be produced by multiple Auger de-excitation are not observed, indicating that their lifetimes are short. The magnetic field at a divalent iron nucleus at low temperature is $2.0 \times 10^5 \text{ oe}$ while that at a trivalent one is $5.6 \times 10^5 \text{ oe}$. The quadrupole coupling in this almost cubic environment is less than 1.0 Mc.

11,418 CROSS PARAMAGNETIC RELAXATION IN CRYSTALS WITH ANISOTROPIC g-FACTOR [in Russian] by Iu. Kh. Kopvillem (Kazan U.); Izv. VUZ, Fiz., No. 3, pp. 50-55, 1961

Formulas for the computation of the cross relaxation time in diamagnetic crystals containing magnetic impurities are presented. It is shown that the energy transition from the system of Zeeman levels to the system of two-particle spin-spin interactions precedes the spin-lattice relaxation process at helium temperatures. A diagram method is worked out for the calculation of the moments of the distribution curve of the characteristic x frequencies of the dipole-dipole interaction. The order of magnitude of the cross-relaxation time in single-crystals of ethyl sulfates of the rare-earth ions is estimated. The possibility of formulating an experiment to verify the theory is discussed.

11,419 ZERO-FIELD SPLITTING OF Cr^{3+} GROUND STATE IN YGa AND YAl GARNET by J. W. Carson and R. L. White (Hughes Labs.); J. Appl. Phys., Vol. 32, p. 1787 (L), Sept. 1961

Paramagnetic resonance spectra of Cr^{3+} in the diamagnetic Ga and Al garnets $\text{Y}_3\text{Ga}_5\text{O}_{12}$ and $\text{Y}_3\text{Al}_5\text{O}_{12}$ are discussed. Measurements were made at 35 kMc, at 300° and 77°K , on oriented simple crystals having 3 per cent of Ga (or Al) sites occupied by Cr^{3+} ions as a result of which the ground state spin quartet is split into two doublets. The data obtained are compatible with the theory of Davis and Strandberg. The sign of the temperature dependence of the zero-field splitting differs in the two garnets. The YAl garnet undergoes a considerable degree of strain. The position of the oxygen members is discussed in the light of the differences between the two garnets.

11,420 CYCLOTRON AND PARAMAGNETIC RESONANCE IN DEFORMED CRYSTALS by G. E. Pikus and G. L. Bir; Soviet Phys.-Solid State, Vol. 3, pp. 730-732 (L), Sept. 1961

Using previously developed methods, a theoretical discussion of resonance effects in deformed crystals of InSb type lattice and

of p-Ge and p-Si type is continued. The spectrum of deformed p-InSb is calculated for both large and small values of K . During a stretching deformation in [100] and [111] directions, the constant energy surfaces are found to have toroidal form. The dependence of resonance frequency on the direction of deformation is calculated for p-Ge and p-Si, and the matrix element W_{12} which determines the probability of transition under the influence of an alternating field is found.

11,421 ELECTRON SPIN RESONANCE AND OPTICAL ABSORPTION OF ELECTRON EXCESS CENTERS IN KCl by P. R. Moran, S. H. Christensen, and R. H. Silsbee (Cornell U.); *Phys. Rev.*, Vol. 124, pp. 442-449, Oct. 15, 1961

The effect of various conditions of optical bleaching and thermal annealing on the electron spin resonance and optical absorption of additively colored KCl is discussed. With extended optical bleaching the resonance linewidth narrows and resonance saturates less readily. The presence of R, M, N, or R' centers is unrelated to the dominant features of the changes in resonance behavior; the optical absorption associated with the magnetic centers appears to remain in the region of the F band.

11,422 ELECTRON SPIN RESONANCE OF AN IRRADIATED SINGLE CRYSTAL OF UREA OXALATE by D. V. G. L. Narasimha Rao and W. Gordy (Duke U.); *J. Chem. Phys.*, Vol. 35, pp. 362-368, July 1961

An investigation by the method of electron spin resonance on free radicals produced in a single crystal of urea oxalate by gamma-irradiation is reported. Only one species of free radical was observed at room temperature. Its form is concluded to be RCHOH with the electron spin density concentrated mostly on the CH carbon. The radical is very stable; its ESR pattern was observed, essentially undiminished, for more than a year after the irradiation. The g factor is only slightly anisotropic, with principal values: $g_u = 2.0024$, $g_v = 2.0048$, and $g_w = 2.0047$. With irradiation and observation at 77°K, a different free radical was observed, one with hyperfine structure from only one H. A description of experimental details is given.

11,423 PARAMAGNETIC RESONANCE OF X-IRRADIATED SINGLE CRYSTALS OF ROCHELLE SALT by G. C. Moulton and W. G. Moulton (U. Alabama); *J. Chem. Phys.*, Vol. 35, pp. 208-212, July 1961

Electron-spin resonances of single crystals of Rochelle salt irradiated with 40 kv x-rays, studied as a function of crystal orientation in a magnetic field, are described. The spectra are time dependent. From decay studies it is deduced that three kinds of centers are present. In Rochelle salt one of these gives rise to an intense doublet which decays rapidly, another to a doublet which grows and then decays, and the third is an eight-line spectrum which grows and is stable. Waters of hydration play an important role in the kinetics of the growth and decay of the centers. The stable spectrum is analyzed; two of the lines arise from breaking one of the C-H bonds. This doublet is slightly anisotropic. A second pair of lines arises from breaking the other C-H bond; since the hydrogens are not equivalent, this pair has a different splitting. The other two pairs are couplings to either OH or water hydration hydrogens.

11,424 ENERGY TRANSFER WITHIN A SPIN SYSTEM by D. F. Holcomb, B. Pedersen, and T. R. Sliker (Cornell U.);

Phys. Rev., Vol. 123, pp. 1951-1957, Sept. 15, 1961

An investigation, by a double-irradiation technique, of the nature of the transfer, within a single nuclear spin system, of energy absorbed from an external source of a radio-frequency magnetic field is discussed. Energy from a high power oscillator running at fixed frequency is absorbed by the nuclear spin system. The frequency of a second, low-level oscillator is then swept through the nuclear resonance, sampling the line shape existing in the presence of the strong RF field from the fixed-frequency oscillator. Particular spin systems investigated were the proton system in single crystalline $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, and the Al^{27} system in aluminum metal. In aluminum, the technique gives direct experimental verification of a completely homogeneous saturation behavior. It also gives further verification of the Redfield saturation theory. In $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, an enhancement effect which allows one to determine the importance of double-flip spin-lattice relaxation processes is observed. The technique could be usefully applied to many spin systems to determine the degree of inhomogeneity in the resonance line broadening.

11,425 BLOCH WALL EXCITATION. APPLICATION TO NUCLEAR RESONANCE IN A BLOCH WALL by J. M. Winter (U. California); *Phys. Rev.*, Vol. 124, pp. 452-459, Oct. 15, 1961

A study of the excitation spectrum of an assembly of electronic spins in a Bloch wall structure made under the assumption of uniaxial anisotropy is discussed. The spectrum may be divided into two branches; one is a specific wall excitation and does not spread outside the wall, the other one is similar to the spin-wave excitation spectrum in a uniform ferromagnet. These calculations are used to study the properties of the nuclear magnetic resonances in a Bloch wall. The relaxation times are evaluated, taking into account the damping of the motion of the electronic spins, and are compared with experimental values. The spin-spin coupling and the variation of the magnetization across the wall are also estimated.

11,426 NUCLEAR TRANSFER EFFECTS IN NUCLEAR MAGNETIC RESONANCE PULSE EXPERIMENTS by D. E. Woessner (Socony Oil); *J. Chem. Phys.*, Vol. 35, pp. 41-48, July 1961

An interpretation of free precession signals derived from nuclei in state environments possessing distinguishable time-averaged resonance line centers and relaxation characteristics is presented. When the nuclei are constrained to particular state environments, the free precession signal is the sum of all the different signals due to the motions of the molecules, ions, or atoms either containing or in the vicinity of the observed nuclei. If the nuclei are allowed to transfer between distinguishable states by some kinetic molecular process such as chemical exchange or internal rotation, the characteristics of the NMR signal are changed. An extension of the analysis by Zimmerman and Brittin of the effects on observable longitudinal (T_1) and transverse (T_2) relaxation times and fractional populations of the states is given. Cases of unequal resonance frequencies are included but not indirect nuclear spin-spin coupling. The mathematical starting point is the set of Bloch equations. Expressions are given for the free precession signals in two pulse experiments.

NMR of Cr^{53} in CrBr_3 - See 11,401

11,427 NUCLEAR RESONANCE OF Sn^{119} IN METALLIC TIN by Yu. S. Karimov and I. F. Shchegolev (Inst. Phys. Problems,

PARAMAGNETISM (Cont'd)

USSR); *Soviet Phys.-JETP*, Vol. 13, pp. 908-910, Nov. 1961

The dependence of the second moment of the absorption line of Sn^{119} on the external magnetic field, measured between 900 and 5800 oe in metallic tin, is discussed. A value of $\delta = 1.0 \times 10^{-3}$ was obtained for the Knight-shift anisotropy. The indirect exchange coupling constant between neighboring nuclei was found to be $A = 2.5$ kc.

11,428 SPECTRAL DIFFUSION IN ELECTRON RESONANCE LINES by W. B. Mims, K. Nassau, and J. D. McGee (Bell Labs.); *Phys. Rev.*, Vol. 123, pp. 2059-2069, Sept. 15, 1961

Spectral diffusion in the inhomogeneous paramagnetic resonance lines of Ce^{3+} and Er^{3+} in CaWO_4 at concentration $\sim 10^{18}$ spins/cc, studied by electron spin echo techniques, is discussed. Measurements show that the spreading of excitation through the line can be approximately described by a diffusion kernel in the form of a Lorentzian function whose width is linear in time. Local field fluctuations due to spin-spin flips and spin-lattice flips appear to be the primary cause of diffusion. In $(\text{Ca}, \text{Ce})\text{WO}_4$ below 4.2°K the lattice time is long and spin-spin flips predominate, leading to a diffusion rate which is independent of temperature. In $(\text{Ca}, \text{Er})\text{WO}_4$ lattice relaxation is more rapid and the diffusion parameter varies as the lattice time. Nuclei of W^{183} in the host crystal have been observed to give a modulation in the envelope of spin echoes but the corresponding local fields are smaller than those arising from electron spins at the concentrations studied.

Paramagnetic Resonance of Cr^{3+} in LaCrO_3 - See 11,412

OPTICAL PROPERTIES

GENERAL

11,429 GERMANIUM BICRYSTALS AND THEIR APPLICATIONS FOR GRAIN BOUNDARY PHOTOCELLS. II. [in German] by H. F. Mataré (Tekade Semicon. Lab.); *Elektron. Rundschau*, Vol. 15, No. 5, pp. 207-211, 1961

The properties of the bicrystal interface as originated from a close overlap of the dangling bonds in a geometrically defined way are described. The degenerate conductivity, the barrier layer action and the good photoelectric sensitivity are considered in detail. The latter property is discussed with respect to the grain-boundary photocell KF11. A few possible applications of this cell are described.

Measurement of the Refractive Index of Surface Oxide Films - See 11,322

ABSORPTION (TRANSMISSION)

11,430 EFFECT OF PRESSURE AND TEMPERATURE ON THE ABSORPTION SPECTRA OF FOUR ALKALI HALIDE PHOSPHORS by A. S. Balchan and H. G. Drickamer (U. Illinois); *J. Chem. Phys.*, Vol. 35, pp. 359-361, July 1961

The effect of pressure and temperature on the "A" bands in LiI and in three alkali halides containing Pb^{++} impurity is discussed. Temperature change imposes a red shift on the

observed room-temperature pressure shift. A new band in the high pressure phase of KCl:Pb and KBr:Pb appears on heating under pressure. The band remains after cooling, but disappears upon lowering the pressure into or through the region of the transformation back to the fcc phase. Repressuring and reheating reintroduces the band. It is probable that the band is associated with the ionic configuration near the Pb^{++} ion; especially with the location of the accompanying K^+ vacancy.

Effect of Pb Impurities upon Absorption Spectra of NaCl and KCl Crystals - See 11,363

11,431 INVESTIGATION OF THE STARK EXCITON EFFECT IN ORIENTED MONOCRYSTALS OF COPPER OXIDE by E. F. Gross, B. P. Zakharchenya, and L. M. Kanskaya (Phys.-Tech. Inst., Leningrad); *Soviet Phys.-Solid State*, Vol. 3, pp. 706-711, Sept. 1961

Experiments concerning electric field action on yellow absorption series in oriented monocrystals of Cu_2O at liquid helium temperatures are described. The phenomenon observed is the Stark exciton effect. The shift of the fundamental terms of the exciton series in an electric field, the behavior of the side lines and the character of their polarization were investigated. Results show the complexity of the energetic system of the exciton states, the existence of the higher multiplicity transitions in the exciton spectrum and a similarity to the strongly excited states of an isolated system. In basic exciton states, degeneracy analogous to that of a purely hydrogen-like system is absent.

11,432 ON THE NATURE OF COLOUR CENTRES IN OXYGEN-DEFICIENT BaTiO_3 SINGLE CRYSTALS by P. Coufova and H. Arend (Czech. Acad. Sci., Prague); *Czech. J. Phys.*, Vol. 11B, pp. 416-423, 1961

The conditions under which oxygen non-stoichiometry of BaTiO_3 single crystals is created by their thermal treatment in atmospheres with different partial pressure of oxygen are discussed. Two bands with maxima at 0.48μ and 0.64μ were found in the visible region in the absorption spectrum of crystals deficient in oxygen. An attempt was made to find an interpretation of the structure of non-stoichiometric BaTiO_3 and a model of the appropriate color center was proposed for the band with a maximum at 0.64μ .

11,433 THE DISCOLORATION SPECTRA OF STRONTIUM FLUORIDE SINGLE CRYSTALS [in German] by H. Karras (Opt. Werke, Jena); *Phys. Status Solidi*, Vol. 1, No. 1, pp. 68-80, 1961

Measured spectra of subtractive and additive coloration of strontium fluoride are discussed. Reproducible types of spectra were obtained. It was found that pure crystals could be colored only slightly by x-rays. After additive coloration, they exhibited an absorption spectrum which is typical of intrinsic defects. Addition of oxygen altered the absorption spectrum before and after the coloration; the coloration spectra found were quite different from those of the intrinsic defects.

11,434 MODEL FOR THE ELECTRONIC STRUCTURE OF THE K AND L BANDS IN ALKALI HALIDES by A. Gold (U. Illinois); *Phys. Rev.*, Vol. 123, pp. 1965-1967, Sept. 15, 1961

A speculative model for the origin of the K and L bands in alkali halide crystals is discussed. They are assigned to transitions of the F_2^+ center (an anion vacancy pair plus an electron). This is plausible under the assumption that there is a plentiful supply of anion vacancies in the crystal and is in

ABSORPTION (TRANSMISSION) (Cont'd)

general qualitative agreement with experiment. In addition, it possesses an advantage over ascribing these bands to transitions of the F center in that it explains the low quantum efficiency for photoconductivity observed in the L region.

Optical Absorption of Electron Excess Centers in KCl - See 11,421

Resonance Absorption of Microwaves in Ferrites - See 11,305

11,435 INFRARED TRANSMITTANCE OF STRONTIUM TITANATE FROM ROOM TEMPERATURE TO -180°C by C. D. Salzberg (Kodak); *J. Opt. Soc. Am.*, Vol. 51, pp. 1149-1150 (L), Oct. 1961

A series of transmittance measurements on strontium titanate samples over a wide range of temperatures is reported. 1-, 3-, 5- and 10-mm samples were cut from single-crystals, and transmittance measurements were performed on a Perkin-Elmer model 21 interferometer. Results indicate that strontium titanate does not suffer any loss of transmittance with cooling, in contradiction with the results of Malitson.

11,436 THE SEMICONDUCTING PROPERTIES OF CdSb by F. Ermanis (Bell Labs.) and E. Miller (NYU); *J. Electrochem. Soc.*, Vol. 108, pp. 1048-1052, Nov. 1961

Measurements of infrared absorption in the $\langle 100 \rangle$ direction of single crystal samples of CdSb are reported. A value for the energy gap at room temperature for indirect transitions of 0.45 eV with a temperature variation of $-6 \times 10^{-4} \text{ eV}/^{\circ}\text{K}$ was found. From resistivity, Hall coefficient and Seebeck coefficient data, the energy gap at 0°K was calculated to be 0.57 eV, the mobility ratio 0.9, and the hole effective mass was found to increase with temperature from 0.2 to 0.38 between 100° and 300°K . The conductivity was found to be anisotropic, the three principal conductivities being in the ratio $\sigma_{010}:\sigma_{100}:\sigma_{001} = 1.45:1.09:1.00$.

11,437 INFRARED ABSORPTANCE OF SINGLE CRYSTAL ANTIMONY by C. Nanney (U. Chicago); *Bull. Am. Phys. Soc.*, Vol. 6, Ser. II, p. 439 (A), Nov. 24, 1961

The absorbance of antimony single crystals measured at room and helium temperatures in the region 2 to 18μ using plane polarized radiation was discussed. Two distinct absorbance maxima have been observed. One is located at 5.7μ for a binary crystal direction normal to the surface and the electric field vector parallel to the trigonal axis. The second is located at 10.6μ for the binary normal and the electric field vector parallel to the bi-sectrix axis. The maximum with the trigonal direction normal is polarization independent and occurs at 10.6μ as expected. The positions of the maxima are essentially temperature independent. These absorbance maxima are interpreted as "dielectric anomalies." These data were discussed in terms of the effective masses of the carriers and their densities.

11,438 INFRARED TRANSMITTANCE OF CRYSTALLINE YTTRIUM OXIDE AND RELATED COMPOUNDS by K. A. Wickersheim and R. A. Lefever (Hughes Res. Lab.); *J. Opt. Soc. Am.*, Vol. 51, pp. 1147-1148 (L), Oct. 1961

Preliminary information on the optical and infrared properties of yttrium oxide and related compounds is summarized. Single crystals of Y_2O_3 have been prepared and examined for color

transmission and the transmittances and refractive indices have been measured. Visible and ultraviolet range properties are sensitive to impurities in initial powders, but this is not so for the infrared region. Transmission curves show an absorption at 3μ , and similar behavior is exhibited by Yb_2O_3 and $(\text{Y}_{0.95}\text{La}_{0.05})_2\text{O}_3$. The infrared characteristics of Y_2O_3 compare favorably with those of sapphire and MgO .

Infrared Absorption in CdSb - See 11,436

11,439 OPTICAL ABSORPTION OF CERTAIN METALLIC IMPURITIES IN THE CRYSTAL LATTICE OF CADMIUM SULFIDE [in Russian] by V. V. Serdiuk and T. Ia. Sera (Odessa U.); *Izv. VUZ, Fizika*, No. 2, pp. 132-137, 1961

Investigations of changes in the absorption spectra of polycrystalline cadmium sulfide layers which are caused by heat treatment and the injection of certain metallic impurities are reported. It is shown that heat treatment of the semiconductor under investigation causes excess absorption in that region of the spectrum where the photo response band is located. Impurities which sensitize the photoconductivity in CdS (silver, copper) also cause the appearance of absorption bands which coincide in location with the photo response bands due to these impurities. Metal impurities, which are quenchers of photoconductivity (iron, nickel, cobalt), increase the absorption in appropriate regions of the spectrum very slightly. The optical absorption effects observed are closely related to the photoconductivity and luminescence phenomena of cadmium sulfide.

11,440 OPTICAL SATURATION OF F-CENTER SPIN RESONANCE by B. R. McAvoy, D. W. Feldman et al. (Westinghouse Res. Labs.); *U.S. Gov. Res. Rep.*, Vol. 36, p. 74 (A), Sept. 5, 1961 AD 258371

Investigations of CW absorption of F-band light by F-centers in KCl crystals at 2°K and 3 kilogauss are described. The CW absorption is found to speed up spin relaxation and to raise the steady state spin temperature. The observations are well fitted to the model of the F-center involving no preferential optical pumping.

11,441 ULTRAVIOLET ABSORPTION SPECTRUM OF AMMONIA IN SOLID ARGON AT 4.2°K by K. Dressler (Natl. Bu. Stand.); *J. Chem. Phys.*, Vol. 35, pp. 165-169, July 1961

A series of absorption bands in the region 1600 to 1900 Å in thin films of solid argon containing between 0.3 per cent and 3 per cent of ammonia is presented. The bands are attributed to isolated NH_3 , and the absence of alternating bands in the observed vibrational progression shows that in the ground state only the $J = 0$ level is appreciably populated. Thermal equilibration of NH_3 at 4.2°K involves the interconversion of nuclear spin species. It is suggested that the observed rapid equilibration is due to coupling between the proton spins and the spin of the nitrogen nucleus.

11,442 OPTICAL ABSORPTION BY POLYCRYSTALLINE LAYERS OF CdS by K. V. Shalimova, T. S. Travina, and L. L. Golik (Moscow Inst. Energetics); *Soviet Phys.-Doklady*, Vol. 6, pp. 396-398, Nov. 1961

Absorption spectra measured in the wave length region 200 to 500 mμ in polycrystalline layers of CdS are discussed. The layers were deposited by evaporating, in a vacuum or in an atmosphere of argon and hydrogen sulfide, on substrates which

were at room temperature, 350° or 450° at the beginning of the evaporation. Similar absorption spectra have been measured in films prepared in a vacuum and in an atmosphere of argon and hydrogen sulfide. A characteristic absorption at 230 mμ, corresponding to 5.36 eV, was observed in all films in which the absorption was measured down to 200 mμ. In the region 300–500 mμ, maxima were observed at 320, 420, and 490 mμ. In this region, the incident light raises electrons in the excess cadmium atoms from the ground state to an excited state. The absorption spectrum indicates that the excess Cd atoms have three excitation energy levels, viz: 3.85, 2.94, and 2.52 eV.

Absorption Edge of GaSb-InSb Alloys - See 11,335

LUMINESCENCE

11,443 EFFECT OF INFRARED IRRADIATION ON ZnS:Cu PHOSPHORS by K. Kallmann and K. Luchner (NYU); *Phys. Rev.*, Vol. 123, pp. 2013-2019, Sept. 15, 1961

Measurements of infrared stimulation and quenching of ZnS:Cu phosphors as a function of trap population are reported. It is found that stimulation at low temperature increases linearly with the concentration of ionized activators and disappears when the shallowest traps are emptied. Quenching increases as the product of the concentration of ionized activators and trapped electrons. From these results it is concluded that the main action of infrared on these phosphors is a shifting of hole levels of higher recombination rate. This model accounts quantitatively for the dependence of stimulation and quenching on the state of excitation. It is strongly supported by infrared effects on the glow and photoconductivity and the similarity of the wave length dependence of stimulation and quenching. Thus the light stimulation observed under infrared irradiation is not due to the usual assumption of a direct release of trapped electrons by infrared, but rather to a shifting of holes to levels of higher recombination rate.

11,444 ON THE BEHAVIOR OF ELECTROLUMINESCENT PHOSPHORS ON IRRADIATION WITH ULTRA-VIOLET by D. G. Ballentyne (U. Hull); *J. Phys. Chem. Solids*, Vol. 21, pp. 131-133(L), Oct. 1961

The enhancement of electroluminescence in ZnS:Cu, Al phosphors by ultraviolet irradiation is described on the basis of a band model. It is suggested that excess Cu in the phosphor produces a p-type phase of cubic material containing hexagonal material with a low concentration of Cu ions. The wave functions of the perturbed states overlap and an impurity band is formed. The p-type cubic material is in contact with less heavily doped n-type hexagonal material. With proper bias, electrons in luminescent centers in the forbidden gap of the n-type material tunnel into the impurity band. When the bias is reversed, the electrons from the impurity band tunnel into states of the conduction band. The electrons then either directly recombine with the ionized luminescent centers or are trapped in the traps. The trapped electrons are thermally released into the conduction band and recombine with the luminescent centers. The recombination is accompanied by an emission of photons of energy $h\nu$. The ultraviolet radiation reduces the occupancy of the impurity band. The number of electrons which can tunnel from the luminescent center is

thus increased. As these electrons are transferred to the traps, the brightness of the emitted light is enhanced.

11,445 ELECTROLUMINESCENCE AT LOW VOLTAGE by J. Weiszburg (Ind. Res. Inst. Telecommun. Tech., Budapest); *Acta Phys. Hung.*, Vol. 13, pp. 61-65, 1961

An experimental investigation of the accepted distinction between intrinsic and injection electroluminescence is reported. It is concluded that there is no foundation for this distinction because the orders of the threshold voltages of the two groups agree with each other. The electroluminescent phenomena of evaporated ZnS layers at low voltages can be well described by regularities characteristic of the Mott-Shottky-type barriers. The existing data are not sufficiently detailed to serve as check of the correctness of the various theoretical hypotheses.

11,446 THE ELECTROLUMINESCENCE OF ZnS-Cu, Mn by S. Damasková and K. Pátek (Czech. Acad. Sci., Prague); *Czech. J. Phys.*, Vol. 11B, pp. 336-343, 1961

An investigation of the brightness waves of ZnS-Cu, Mn phosphor is reported. It has been found that their shape changes from that characteristic for copper-activated phosphors to that characteristic for manganese-activated phosphors as a function of the magnitude of the voltage applied, the length of the pulses and the temperature. In order to explain the results it is assumed that simultaneously with the mechanism of electroluminescence, accepted for ZnS-Cu (ionization of activators; recombination and radiation delayed in phase compared with voltage), there exists an immediate recombination of the Cu activators in the barriers which is accompanied by radiation in phase with the voltage.

11,447 EFFECTS OF INTERACTION AMONG PARTICLES IN ELECTROLUMINESCENT LAYERS by A. T. Halpin and P. Goldberg (Genl. Tel. Electronics); *J. Electrochem. Soc.*, Vol. 108, pp. 1028-1034, Nov. 1961

The optical and electrical behavior of electroluminescent layers are discussed in terms of experimentally determined properties of individual phosphor grains modified by interactions with neighboring particles. Pronounced interaction effects have been found and studied by determining the dependence of cell brightness and electrical dissipation on variables that alter the degree of particle-particle interaction, i.e., phosphor volume fraction and fluidity of embedment medium. One result of interactions between particles is to increase the average luminous flux per unit volume of phosphor as volume fraction increases. A statistical analysis which correctly describes this effect in terms of the number of particles in contact in the layer is given. Two purposes for evaluating the role of particle interaction in determining the dielectric properties of the phosphor are discussed.

11,448 ANALYSIS OF P-N LUMINESCENCE IN Zn-DOPED GaP by H. G. Grimmeiss and H. Koelmans (Philips); *Phys. Rev.*, Vol. 123, pp. 1939-1947, Sept. 15, 1961

An investigation of p-n luminescence and photoluminescence of Zn-doped GaP is described. Spectral distributions and the light output as a function of temperature and excitation density have been recorded. The light output of the p-n luminescence shows a strongly superlinear dependence on excitation density. With rising temperature, the superlinear range shifts to higher excitation densities. Using a three-level model the recombination kinetics are analyzed with the aid of the Klasens

LUMINESCENCE (Cont'd)

code-number method. The analysis given allows an interpretation of the superlinearity and gives a quantitative explanation of the observed shift of the superlinear range with temperature.

11,449 P-N LUMINESCENCE IN GALLIUM PHOSPHIDE by H. G. Grimmeiss and H. Koelmans (Philips, GmbH); Philips Tech. Rev., Vol. 22, pp. 360-361, 1960/1961

P-N luminescence in GaP is discussed. By improved activation, due to the introduction of "deep" and "shallow" levels which act as traps, it has proved possible to raise the efficiency of the luminescence by a factor between 100 and 1000 compared with the values previously achieved. It was thus possible to take color photos (Kodachrome) with an exposure time of only one minute. Further developments are in progress, particularly with a view to the application of the luminescence in electro-optical devices, e.g., in combination with a CdS photoresistor. Color photos of p-n luminescence from polycrystalline samples of GaP are presented.

Infrared Luminescence in Tunnel Diodes - See 11,480

11,450 THE RELATIONSHIP BETWEEN THE EDGE LUMINESCENCE AND THE STRUCTURE OF THE FUNDAMENTAL ABSORPTION EDGE by E. F. Gross and R. I. Shekhmamet'ev (Zhdanov State U.); Soviet Phys.-Solid State, Vol. 3, pp. 647-650, Sept. 1961

An investigation of the luminescence of As_2S_3 , Bi_2O_3 , V_2O_3 , and MoO_3 near the absorption edge is reported; no traces of luminescence were found. The method was checked using other compounds, also without structure at the absorption edge. A clear correlation between absorption structures and edge luminescence was found in HgI_2 crystals. The experiments indicate that edge luminescence occurs only in substances with fundamental absorption edge structure. Preliminary experiments were also carried out on the excitation spectra of the yellow-green and red luminescence of red HgI_2 , and broad luminescence bands were found which correlate with absorption lines.

11,451 STIMULATED EMISSION INTO OPTICAL WHISPERING MODES OF SPHERES by C. G. B. Garrett, W. Kaiser, and W. L. Bond (Bell Labs.); Bull. Am. Phys. Soc., Vol. 6, Ser. II, p. 414(A), Nov. 24, 1961

Observations made on the exposure of spherical samples of $CaF_2:Sm^{2+}$, maintained at 20°K, to high-intensity pulsed illumination were discussed. When the intensity exceeds a certain well-defined threshold, the character of the emission of fluorescent light from the surface of the sphere changes. As the intensity is raised beyond the threshold, an increasing fraction of the light is emitted nearly tangentially from each point on the surface. The light emitted in this way is polarized with the E vector radial. The observations were interpreted as indicating stimulated emission oscillations in "whispering modes" of the sphere, which have been analyzed in terms of the electromagnetic analog of the Rayleigh theory of the whispering gallery.

11,452 PHOSPHOR EFFICIENCY AT VERY LOW EXCITATION CURRENT DENSITIES by G. W. Francis and R. G. Stoudenheimer (RCA); Rev. Sci. Instr., Vol. 31, pp. 1246-1247, Nov. 1960

Measurements of the luminescence efficiency of ZnS:Ag phosphor

screens as a function of excitation current density are reported. The luminescence efficiency of aluminized screens operated at 15 kv was found to decrease from an almost constant value of 7.4 lm/w to a constant value of 4 lm/w as the excitation current density changed from about 3×10^{-11} to 3×10^{-13} amp/cm². The experimental arrangement is described.

PHOTOELECTRONIC PROPERTIES

11,453 ON THE THEORY OF THE TRAP MECHANISM IN SEMICONDUCTORS [in German] by M. Heywang and M. Zerbst (Siemens and Halske); Z. Naturforsch., Vol. 14a, No. 7, pp. 641-645, 1959

The influence of traps on the photoconductivity of semiconductors in the cases of constant excitation and increasing or decreasing excitation is discussed. The experimental values which can be measured (including temperature variations) permit the determination of all the characteristic constants, that is trap density, energy levels, and effective cross section for electrons and holes.

11,454 KINETICS OF THE PHOTOCONDUCTIVITY OF LAYERS OF AMORPHOUS SELENIUM TREATED WITH MERCURY VAPORS [in Russian] by M. I. Korsunskii, N. S. Pastushchuk, and G. D. Mokhov (Khar'kov Polytech. Inst.); Izv. VUZ, Fizika, No. 4, pp. 167-172, 1960

Measurements of the photoconductivity of amorphous Se layers subjected to the effect of mercury vapors, which disclose simultaneously a positive and negative photoconductivity, are reported. Investigations have shown that the kinetics of the photoconductivity of these layers depends substantially on the spectral composition of the light, its intensity and the direction of the applied electric field. Negative photoconductivity is observed under the effect of visible shortwave radiation of sufficient intensity. As the wave length increases for a given light intensity, the drop in the positive photoconductivity diminishes in the light.

Photoconductivity of Ge Grain Boundaries - See 11,429

11,455 PHOTOCONDUCTION IN CADMIUM SULPHIDE by J. F. Duncan and D. N. Sitharama Rao (U. Melbourne); Brit. J. Appl. Phys., Vol. 12, pp. 511-513, Sept. 1961

Discrete voltage pulses, of amplitude depending on the energy of the incident radiation, observed in the photoconduction of cadmium sulphide at room temperature are discussed. Between 4800 Å and 8000 Å the pulse height varies with wave length in a similar manner to the photocurrent. Below 3500 Å it is closely proportional to the energy of the radiation. CdS can be used as a spectrophotometric device in this region when only small numbers of quanta are available.

Photoconductivity of Alloys of the Sulfides of Thallium, Antimony and Bismuth - See 11,375

11,456 THERMAL ACTIVATION ENERGIES OF DARK CONDUCTIVITY IN ORGANIC COMPOUNDS by A. T. Vartanyan and L. D. Rozenshtein (Vavilov State Opt. Inst.); Soviet Phys. Solid State, Vol. 3, pp. 520-526, Sept. 1961

Measurements of the temperature dependence of the dark conductivity activation energy of various organic dyes are reported

PHOTOELECTRONIC PROPERTIES (Cont'd)

The experiment was carried out in vacuo over the temperature interval 50°–100°C using a sublimation technique. The absorption spectra of solid films of various compounds were also measured. Comparison of the energy values with the position of the shortwave edges of phosphorescence bands, and with regions of longwave descent of the absorption curves show that free carriers participating in dark conductivity are created by singler-doubler electron transition activation. The above temperature dependence was also measured in oxygen atmosphere for oxygen xanthene dyes. In high temperature regions, conductivity behaves similarly to that in vacuo, but there is distortion at low temperatures.

11,457 THE PHOTOELECTRIC PROPERTIES OF SOME COMPOSITIONS WITH ZINCBLENDE LATTICE [in Russian] by N. A. Goryunova, W. S. Grigorieva, B. M. Konavelenko, and S. M. Ryvkin (USSR Acad. Sci.); *Zhurn. Tek. Fiz.*, Vol. 25, pp. 1675–1682, 1955

The results of an investigation of the spectral distribution of the photoconductivity of the binary alloys Ga_2Se_3 , Ga_2Te_3 , Sn_2Te_3 , and ternary alloys $Ga_2Te_3 \cdot ZnTe$, $Ga_2Te_3 \cdot 3ZnTe$, $Ga_2Te_3 \cdot 9ZnTe$ are reported. Graphs representing corresponding relations are given. All of the materials were found to be semiconductors with photosensitive properties. Dependencies based on the content of ZnTe in ZnTe series alloys were observed. The width of the forbidden band, the activation energy, relative photosensitivity and conductivity of the compositions are tabulated.

Photoconductivity of Tl-Sb-Se Compounds - See 11,374

11,458 PHOTOCONDUCTION IN TERNARY V-VI-VII COMPOUNDS by R. Nitsche and W. J. Merz (RCA Labs., Md.); *J. Phys. Chem. Solids*, Vol. 13, Nos. 1–2, pp. 154–155, 1960

The preparation and photoelectric properties of single crystals of $SbSBr$, $SbSI$, $SbSeBr$, $SbSeI$, $BiSeI$, $BiSBr$, $BiSI$, $BiSeCl$, $BiSeBr$, and $BiSeI$ are discussed. The compounds can be prepared by reacting equivalent amounts of the elements between 500° and 600°C in sealed, evacuated glass ampoules. A mixture of a group V trihalide and the corresponding group V trichalcogenide, e.g., $SbBr_3 + Sb_2S_3 \rightleftharpoons 3SbSBr$, can be used to avoid the use of gaseous halogens. Single crystals up to 1 cm in length have been obtained. The wave lengths of the maximum photocurrent, λ_{max} , shift in a regular way towards longer wave lengths with increasing atomic weight of the components. For the compounds $SbSBr$ and $SbSI$, the temperature dependence of photocurrent, dark current, and λ_{max} between -140° and +120°C has been measured.

11,459 PHOTOVOLTAIC EFFECTS IN Cs_3Sb FILMS by F. Krooten (U. California); *J. Appl. Phys.*, Vol. 32, pp. 1789–1790 (L), Sept. 1961

Photovoltaic effects in Cs_3Sb films are reported. 200°–500°A films of Cs_3Sb were prepared by standard techniques. Previously deposited aluminum strips provided electrical contacts at the ends of the films. Measurement of thermoelectric power indicated p-type conductivity and average luminous sensitivity was $0.1 \mu A/lm$. When the films were scanned with a small light spot from one electrode to the other, photovoltaic effects were often observed. These could be correlated with either the presence of scratches ($< 5 \mu$ wide) in the glass substrate or specks of the

polishing agent CeO_2 ($\sim 5 \mu$ wide). Effects of opposite signs with no such correlation also appeared. Some evidence of enhanced photoemission was also found.

11,460 ON THE NEGATIVE PHOTO-EFFECT IN A METAL-SEMICONDUCTOR CONTACT [in Russian] by A. Yu. Leiderman (Phys.-Tech. Inst. An Uzb SSR); *Izv. AN Uzb SSR, Fiz.-Mate. Nauk*, No. 1, pp. 54–64, 1961

The illuminated contact between an electron semiconductor having one strongly ionized impurity and a metal is discussed. An analysis of the volt-ampere characteristic of the contact between a metal and an electron semiconductor with a barrier layer shows the following for the case of illumination in the impurity absorption band: 1) the barrier penetrability for each kind of carrier determines which of the carriers will predominate in the current; 2) if majority carrier current occurs, then a negative photo-effect is possible under definite conditions; and 3) when hole current predominates, the illumination always causes an increase in the reverse current.

Photovoltaic Effects in CdS Junctions - See 11,512

ELECTROMAGNETIC PROPERTIES

Reflection Spectra of Ge-Si Alloys - See 11,334

11,461 MEASUREMENT OF THE REFRACTIVE INDEX OF LUCITE BY RECOILLESS RESONANCE ABSORPTION by L. Grodzins and E. A. Phillips (MIT); *Phys. Rev.*, Vol. 124, pp. 774–776, Nov. 1, 1961

A method of frequency-modulating a monochromatic electromagnetic wave by varying the optical path length between the source and detector is described. The method has been applied to the measurement of the refractive index of Lucite for the 0.86 Å radiation emitted by Co^{57} ; the small frequency shift was detected by recoilless resonance absorption. The refractive index was found to be $1-n = (1.29 \pm 0.03) \times 10^{-6}$, in agreement with classical theory.

11,462 ON THE FARADAY EFFECT IN MANY-VALLEY SEMICONDUCTORS by L. Gold (U. Michigan); *J. Phys. Soc. Japan*, Vol. 16, p. 1471 (L), July 1961

A basic relation which describes the Faraday rotation in n-type Ge is derived. The familiar Appleton-Hartree relation can be deduced from the general expression if the scalar mass limit is imposed. The physical significances of the relation are discussed. A resonance behavior may be expected in the Faraday rotation.

11,463 DEPENDENCE OF THE FREE-CARRIER FARADAY ELLIPTICITY IN SEMICONDUCTORS ON SCATTERING MECHANISMS by J. K. Furdyna and M. E. Brodwin (Northwestern U.); *Phys. Rev.*, Vol. 124, pp. 740–744, Nov. 1, 1961

The theory of the Faraday ellipticity in semiconductors is developed. The Boltzmann transport equation, under the assumption of an isotropic energy-dependent relaxation time τ , provides the basis of the derivation. Equations relating ellipticity to semiconductor parameters are derived for various ranges of the collision, cyclotron, and applied frequencies. It is observed that, besides its dependence on the value of the scattering parameter, Faraday ellipticity is rather sensitive to the type of scattering mechanism as such, and to the distribu-

ELECTROMAGNETIC PROPERTIES (Cont'd)

tion function. Some specific experiments in the ranges where ellipticity appears particularly promising as a tool for investigating these aspects of the scattering process are suggested. Numerical examples, calculated for thermal and ionized impurity scattering in nondegenerate carrier systems, are contrasted with the results of the constant $-\tau$ approximation, showing the inadequacy of the latter approach. Finally, the effect of spheroidal surfaces of constant energy of Faraday ellipticity is briefly discussed.

OPTICAL PROPERTIES OF SPECIFIC MATERIALS

11,464 OPTICAL CONSTANTS OF LiF IN THE EXTREME ULTRAVIOLET by R. Kato (Kyoto U.); J. Phys. Soc. Japan, Vol. 16, p. 1476, July 1961

Reflection and absorption spectra of LiF single crystals are reported. The values of reflectivity in the transparent region are corrected by the theory of multiple reflection and the phase associated with the reflection characteristic is computed by using the Kramers-Kronig relation. Variations of the refractive index and extinction coefficient versus photon energy are calculated from the phase and reflectivity. Real and imaginary parts of dielectric constant are plotted.

THERMAL PROPERTIES

11,465 LOW-TEMPERATURE SPECIFIC HEAT OF GERMANIUM by C. A. Bryant and P. H. Keesom (Purdue U.); Phys. Rev., Vol. 124, pp. 698-700, Nov. 1, 1961

Electronic and lattice contributions to the specific heat measured in several n-type degenerate Ge ingots are discussed. The electronic effective mass, calculated on the assumption of a parabolic conduction band, is not strongly dependent on donor concentration in Ge. The Debye temperature decreases as donor or acceptor impurities are added, from 371°K for pure Ge to 362°K for the most heavily doped ingot. This marked decrease did not occur in silicon-doped Ge. It is suggested that the effect is due to screening of long-range lattice forces by free electrons or holes.

11,466 NUCLEAR SPECIFIC HEAT OF HOLMIUM by J. E. Gordon, C. W. Dempsey, and A. T. Soller (Amherst Coll.); Phys. Rev., Vol. 124, pp. 724-725, Nov. 1, 1961

Measurements of the specific heat of Ho between 0.95° and 4.2°K are reported. The magnetic hyperfine interaction in Ho is so large that over this entire temperature range the nuclear hyperfine term represents the predominant contribution to the specific heat. Below 1.5°K the specific heat appears to be that of an ideal paramagnetic gas of spin 7/2. At 1°K the specific heat has the extremely large value of 0.37R.

11,467 SPECIFIC HEAT OF SODIUM AT LOW TEMPERATURES by D. L. Martin (Nat'l. Res. Council, Ottawa); Phys. Rev., Vol. 124, pp. 438-441, Oct. 15, 1961

Specific heat measurements in the temperature range 0.4° to 1.5°K on two samples of Na metal are reported. A thermal cycling procedure was used to partly inhibit the martensitic

transformation and thus obtain information on the properties of the two phases of Na. It is concluded that the electronic specific heat coefficient (γ) of the bcc phase is probably slightly larger than that of the hcp phase but with 95 per cent confidence the difference does not exceed 20 per cent. A statistically significant variation (of unknown cause) of the apparent γ of one sample was observed. It is suggested that the wide variation in experimental γ values reported may be due to this cause rather than to the martensitic transformation.

11,468 SPECIFIC HEAT OF A BODY-CENTERED CUBIC Cr-Fe ALLOY BETWEEN 30° AND 110°K by C. T. Wei (Michigan State U.), and C. H. Cheng (U. Illinois); Phys. Rev., Vol. 124, pp. 722-723, Nov. 1, 1961

Measurements of the specific heat of a body-centered cubic alloy, $\text{Cr}_{80.6}\text{Fe}_{19.4}$, between 30° and 110°K are reported. The electronic specific heat coefficient γ and the Debye characteristic between 40° and 60°K were found to be $(46 \pm 5) \times 10^{-4}$ cal mole⁻¹ deg⁻² and $472 \pm 14^\circ\text{K}$, respectively. The origin of a sharp peak occurring at $37 \pm 2^\circ\text{K}$ is discussed.

11,469 EFFECT OF THE PRECIPITATION OF DISSOLVED MnCl_2 ON THE LOW-TEMPERATURE THERMAL CONDUCTIVITY OF NaCl by M. V. Klein (Cornell U.); Phys. Rev., Vol. 123, pp. 1977-1985, Sept. 15, 1961

Low temperature thermal conductivity measurements made on NaCl crystals doped with 10^{-4} mole fraction MnCl_2 are discussed. The manganese ions were first quenched into approximate solid solution and then allowed to age at room temperature. Approximate kinetics of the precipitation that resulted were measured by electron spin resonance. There was surprisingly little change in the conductivity during aging; in particular a low temperature decrease did not appear. It is concluded that the presence of clusters cannot be used to explain the greater than Rayleigh scattering cross section often observed with point defects at low temperatures. The small conductivity changes that did result were: (1) a depression at temperatures near that of the conductivity maximum, and (2) a gradual rise at higher temperatures towards the values obtained with an undoped crystal. These changes were most rapid near the end of the clustering process and suggest a change in the nature of the precipitate at this stage.

Thermal Conductivity and Thermal Expansion of In_2Te_3 and Ga_2Te_3 - See 11,371

Thermal Conductivity of Bi_2Te_3 Alloys - See 11,516

Transient Effect in Peltier Coolers - See 11,516

Thermoelectric Properties of GaAs - See 11,359 and 11,372

Thermoelectric Properties of Solid Solutions of HgTe-HgSe , HgTe-HgS , and HgSe-HgS - See 11,373

Thermoelectric Powers of Solid Solutions in the $\text{AgSbSe}_2\text{-AgSbTe}_2\text{-AgBiSe}_2\text{-AgBiTe}_2$ System - See 11,251

11,470 ON THE THERMODIFFUSION MECHANISM IN FLUIDS by V. B. Fiks; Soviet Phys.-Solid State, Vol. 3, pp. 724-726 (L), Sept. 1961

A possible mechanism for the appearance of the thermodiffusion of impurity atoms in fluids (the Soret effect) is described. The mechanism of internal evaporation is not thought to change, as in other explanations, but is rather supplemented. In a condensed medium, thermal motion is realized in collective motions in addition to atomic transitions. The temperature

radient creates asymmetry in the collective motions and creates a directional flow of phonons. It is assumed that the scattering of thermal vibrations is equivalent to some directional sound pressure on the particle. The pressure of phonons on an impurity atom is calculated in two ways, and the flow of impurity particles is expressed in terms of this and the Soret coefficients. Calculated values of the Soret coefficient are of the same order of magnitude as experimental values.

Thermal Behavior of Cylindrical Solid Dielectrics - See 11,345

MECHANICAL PROPERTIES

11,471 MEASUREMENT OF STRESS IN VERY THIN ELECTRODEPOSITS by H. Watkins and A. Kolk (Natl. Cash Register); Electrochem. Soc., Vol. 108, pp. 1018-1023, Nov. 1961

Stress measurements in very thin electrodeposits, made by a modified form of the Brenner-Senderoff contractometer, are described. Greater sensitivity is achieved by using jeweled bearings and optical readout. The instrument is sensitive enough to yield quantitative stress data in films as thin as 40 Å average thickness. This instrument has been used to study the initial growth of the plating in thin electrodeposited films of Ni and Fe-Ni alloys. Electron micrographs of the films were made to help in interpreting the stress data.

Magnetostriction Constant of Ni - See 11,406

11,472 ON THE ELASTIC CHARACTERISTICS OF CRYSTAL LATTICES WITH THE WURTZITE STRUCTURE. I. EXPERIMENTAL INVESTIGATIONS IN HEXAGONAL CADMIUM SULPHIDE SINGLE CRYSTALS [in German] by E. Gutsche (Phys. Tech. Inst., Acad. Sci., Berlin); Phys. Status Solidi, Vol. 1, pp. 1, pp. 30-36, 1961

Measurements of the linear compressibilities and of the complete set of the five independent elastic constants of hexagonal cadmium sulphide single crystals are reported. The measured quantities show an approximate elastic isotropy and furnish a remarkable violation of the Cauchy relations.

11,473 ON THE ELASTIC PROPERTIES OF THE CRYSTAL LATTICE WITH WURTZITE STRUCTURE. II. THE ELASTIC BEHAVIOR OF THE WURTZITE AND ZINCBLLENDE LATTICE IN A MODEL WITH CENTRAL FORCES BETWEEN NEAREST AND NEXT NEAREST NEIGHBORS [in German] by E. Gutsche (Phys. Tech. Inst., Germ. Acad. Sci.); Phys. Status Solidi, Vol. 1, pp. 2, pp. 147-159, 1961

Under the assumption of central forces and interactions between next and next-nearest neighbors, the elastic properties of crystal lattices with the Wurtzite structure are theoretically investigated. Expressions for the elastic constants, the compressibility, and the optical frequency limits are derived and compared with experimental data. The zinc blende lattice is treated in the same approximation. Analogies and symmetry-induced differences between the elastic behavior of both structures are discussed.

11,474 STUDY OF THE MICROHARDNESS OF CERTAIN SEMICONDUCTORS WITH THE ZINC BLENDE STRUCTURE by A. S. Shchegvskii, N. A. Goryunova and N. K. Takhtareva;

(USSR Acad. Sci.); Soviet Phys.-Tech. Phys., Vol. 2, pp. 1301-1305, 1957

The microhardness of about sixty samples of various semiconducting compounds is tabulated and reported. The microstructure of the polished and etched samples was also investigated. In general, the microhardness was found to be inversely proportional to the strength of the ionic bond. New etching techniques were developed for several of the sample materials.

11,475 INVESTIGATION OF LOW-TEMPERATURE ULTRASONIC ABSORPTION IN FAST-NEUTRON IRRADIATED SiO₂ GLASS by R. E. Trakna (U.S. Naval Ord. Lab. and U. Connecticut); Phys. Rev., Vol. 123, pp. 2020-2026, Sept. 15, 1961

Ultrasonic attenuation measurements made in normal and fast neutron-irradiated fused silica from 7 to 50 Mc and from 1.5° to 200°K are discussed. A broad attenuation curve, attributed to a structural relaxation with a distribution of activation energies, occurs at low temperatures. The shape of the loss curve is dependent upon the distribution of activation energies and the amplitude is proportional to the number of structural units which contribute to the relaxation process. Heavy fast neutron irradiation produced no change in the shape of the curve while the amplitude decreased markedly. A loss associated with a specific defect, an elongated Si-O-Si bond with two equilibrium positions for the bridging oxygen atom, is consistent with results of this study. The presence of a large number of these defects suggests a new concept of the structure of glass. Evidence which shows that thermal spikes, rather than displacement collisions alone, are responsible for the fast neutron damage in SiO₂ is presented.

11,476 LOW-TEMPERATURE INTERNAL FRICTION PEAKS IN SINGLE CRYSTALS OF NaCl AND LiF by A. Taylor (Cornell U.); J. Appl. Phys., Vol. 32, pp. 1779-1780 (L), Sept. 1961

Observations of internal friction peaks in single crystals of NaCl and LiF are described. The internal friction of the compound was measured at both 40 kc and 6 kc, by observing the decay in the amplitude of oscillation after the driving force had been interrupted. The determinations were made in cooling from room temperature to 100°K, and then in heating from 20° to 120°K; an apparatus due to Easwell consisting of a two-part composite oscillator was used. There is a well defined internal friction peak at 100°K on an NaCl crystal deformed until it was birefringent, and at 60°K peak on a slightly deformed crystal of NaCl. The method of Paré was also used for LiF at 6 kc with similar results. Experiments on more highly strained crystals showed higher peaks at slightly increased temperatures.

SOLID STATE DEVICES

RESISTORS

11,477 HIGH TEMPERATURE RESISTORS FOR PRINTED CIRCUITS by R. B. Belser and D. W. Robertson (Georgia Inst. Tech.); U.S. Gov. Res. Rep., Vol. 35, pp. 725-726 (A), June 16, 1961 PB 154 166

Measurements of the temperature coefficient of resistance (TCR) of refractory and semi-refractory metal films deposited on fused quartz substrates by sputtering over the range 25° - 600°C in

vacuo are reported. Selected specimens were subsequently temperature cycled in air and the temperatures at which irreversible changes in resistance occurred were recorded. The metals examined fall into three general classes: members of the platinum family (Pt, Os and Ru), the semirefractory metals (Ti, Zr, V, Nb), and the refractory metals (Mo, Re, W). The metals of the platinum family, with the exception of Os, exhibited TCR values in the approximate range $1/4$ to $1/2$ the TCR of the bulk metal but were too high to be of value as normal resistor units. On the other hand, similar films were utilized with success as resistor thermometers. The semi-refractory metals were attacked by residual gases during the sputtering action to form metal compounds, nitrides or oxides. Films of these materials gave negative TCR values. The refractory metals exhibited low TCR values and high stabilities. Studies of the protection provided 42 films of tungsten or rhenium by overcoats of silicon monoxide, silicon or chromium were conducted. In some instances protection for five or more cycles to 600°C in air were observed without film damage and power dissipation tests to approximately 800°C were performed successfully.

DIODES

11,478 DERIVING THE TUNNEL DIODE CURVE by F. H. Mitchell, Jr. (Chrysler); Electronic Ind., Vol. 20, pp. 96-97, Oct. 1961

A semi-empirical tunnel diode characteristic curve that includes the excess current is derived. The derivation is based upon the integral I-V characteristic curve predicted by quantum mechanics for a slightly forward-biased tunnel diode. The various constants and distributions used in the derivation are graphically illustrated.

11,479 FREQUENCY LIMITATIONS OF TUNNEL DIODES by M. Muller, Nachrichtentech. Z., Vol. 14, pp. 165-169, Apr. 1961

A practical estimate of the upper frequency limit, f_0 , of tunnel diodes based on an analysis of the tunnel diode equivalent circuit and consideration of the geometry and size of the semiconductor is presented. The optimum current density for maximum f_0 is given by $J_{\text{opt}} = 11 f_0$ amp/mm² where f_0 is in gigacycles. It can also be shown that the semiconductor disk height, h , for Ge is related to f_0 (assuming $h = 2r$) by $h = 0.0316 \{[(34.5 f_0) + 1]^2 - 1\}$ mm. A 10 Gc upper frequency limit corresponds to $h = 0.035$ mm, the smallest size which appears to be practical.

11,480 SOME NEW MEASUREMENTS OF INFRARED LUMINESCENCE IN TUNNEL DIODES by J. I. Pankove (RCA Labs.); J. Electrochem. Soc., Vol. 108, pp. 998-1000, Oct. 1961

Infrared luminescence observed in Ge tunnel diodes by means of an integrated source-detector technique is discussed. The diodes were constructed by double recrystallization from an alloy solution onto a block of Ge on which two ohmic contacts were also attached. A dc voltage was applied to the ohmic contacts and the photoconductivity due to the light emitted by the diode was measured. The spectral sensitivity of the photoconductor is determined by the impurities in the Ge and excellent optical coupling is achieved by constructing the source and detector in same piece of semiconductor. Measurements have been made

using compensated gold-doped and intrinsic Ge detectors.

11,481 ON THE QUESTION OF THE INFLUENCE OF "DEEP" IMPURITIES ON THE VOLT-AMPERE CHARACTERISTICS OF SEMICONDUCTING DIODES [in Russian] by P. M. Karageorgii-Alkalev (Phys.-Tech. Inst. AN Uzb SSR); Izv. AN Uzb SSR, Fiz.-Mate. Nauk, No. 2, pp. 12-28, 1961

The influence of "deep" impurities on the I-V characteristics of thin base semiconductor diodes is discussed. Deep impurity influences must be taken into account in diodes in which the dimensions of one of the homogeneous domains are comparable to or less than the diffusion length of the minority carriers. This effect is associated with the modulation of the size of the quasi neutral domain in the thin base by the external voltage. Substantial changes in the I-V characteristics of these diodes are reported.

11,482 ELECTROLUMINESCENCE AT p-n JUNCTIONS IN GALLIUM PHOSPHIDE by M. Gershenzon and R. M. Mikulyak (Bell Labs.); J. Appl. Phys., Vol. 32, pp. 1338-1348, July 1961

The preparation of both diffused and alloyed junctions from single crystals of GaP is described. The diodes are characterized by their current-voltage relationship and their capacity at reverse bias. Anomalies in both the forward and the reverse currents, an excess capacity, and a hysteresis effect are attributed to the presence of deep centers in the depletion layer, particularly in the alloyed structures. A nearly compensated layer was found at the junction of the diffused diodes. The spectra, bias dependences, decay times, and efficiencies of the electroluminescence emitted at these junctions at both forward and reverse bias were studied and correlated with the diode models. At reverse bias, radiative intraband relaxation was due to carriers excited during avalanche breakdown (diffused diodes), by internal field emission (alloyed diodes), and from carriers thermally generated within the depletion layer (all diodes). At forward bias, only the diffused junctions exhibited light emission and this was of two types: (1) a band-to-band recombination with phonon cooperation, whose recombination kinetics depended on whether or not the process occurred within the depletion layer, and (2) recombination through a deep level which may be associated with a vacancy.

11,483 OXIDATION-INDUCED DEGRADATION OF REVERSE CHARACTERISTICS OF SILICON DIODES by C. R. Fuller and S. S. Baird (Texas Instr.); J. Electrochem. Soc., Vol. 108, p. 262C (A), Dec. 1961

The degradation of certain reverse characteristics of Si diodes as a result of their oxidation was discussed. It was shown that this degradation results in part from a surface rearrangement of the diffused dopant, and that the extent of the degradation can be controlled by controlling the surface concentration of the diffusant.

11,484 ON THE REVERSE CHARACTERISTICS OF GERMANIUM JUNCTION DIODES by A. Lőrinczy and G. Pataki (Res. Inst. Tech. Phys. Hung. Acad. Sci.); Acta Phys. Hung., Vol. 13, pp. 67-72, 1961

The reverse characteristics of Ge junction diodes in the temperature range of 200° – 340°K are discussed. It has been found that the reverse current, instead of showing saturation, changes linearly with the voltage. On the basis of the temperature dependence of the slope of the linear section, a shunting effect caused by an adsorbed water layer is deduced. From the tem-

temperature dependence of the defined saturation current a value 0.70 eV has been derived as the energy gap of Ge.

11,485 LOCALIZED LOW BREAKDOWN IN DIFFUSED SILICON DEVICES by P. S. Flint (Fairchild Semicon.); J. Electrochem. Soc., Vol. 108, p. 261C (A), Dec. 1961

Studies on the "pipe" phenomenon, a principal cause of low breakdown in diffused Si junctions, were discussed. The electron probe x-ray microanalyzer was employed as a tool for determining the chemical composition of pipes. The roles of both bulk properties and surface cleanliness in pipe formation were discussed, and some methods for the prevention of pipes were proposed.

11,486 ON THE THEORY OF THE VOLT-AMPERE CHARACTERISTIC OF A SEMICONDUCTOR DIODE WITH A SMALL ALTERNATING SIGNAL [in Russian] by D. A. Aronov (Phys.-Tech. Inst. AN Uzb SSR); Izv. AN Uzb SSR, Fiz.-Mate. Nauk, No. 1, pp. 65-74, 1961

The I-V characteristic of a reverse biased semiconductor diode under small ac signal conditions is discussed. A formula for the I-V characteristic of a diode having a sharp p-n junction in which the thickness of one of the regions is comparable to or even considerably less than the diffusion length of the minority current carriers is derived. The influence of the effective recombination rate at the electrode surface on the frequency dependence of the capacitance and impedance is taken into account in the case of "thin" diodes. An increase in the reverse bias weakens the frequency dependence of the capacitance and impedance.

11,487 MEASUREMENT OF THE THERMAL RESISTANCE OF SEMICONDUCTOR POWER DIODES [in Czech] by V. Rychtářík (Res. Inst. Tech., Popova); Elektrotech. Obzor, Vol. 50, No. 9, pp. 488-491, 1961

Thermal conditions in a semiconductor diode are considered. Methods of measuring the temperature of the crystal and the surface of the casing are described. The calculation of the electric losses of the diode and a connection diagram for the measurement of the thermal resistance are given.

11,488 PREPARATION OF SEMICONDUCTOR DEVICES HAVING NON-UNIFORM JUNCTIONS by J. W. Faust, Jr. (Westinghouse); U.S. Pat. 3,009,841, Issued Nov. 21, 1961

A technique for preparing uniform p-n junctions is described. The surface of the semiconductor wafer is abraded, for example by lapping, saw cutting, or sand blasting. The abrasion process produces a highly damaged region at the surface of the wafer. Impurity is then diffused into or alloyed onto the damaged surface. The doping material in both cases diffuses rapidly down through the mechanically produced dislocations. Since there is a very high, uniform density of these dislocations, the impurity becomes uniformly diffused throughout the area to which it is applied and a diffusion front which has a uniform impurity density results. The impurity penetrates the two damaged regions to the undamaged region where a junction is formed. The damaged regions are then removed by etching. In the case of alloying, the abraded surface prevents the uncontrolled spreading of the impurity, and produces a deep penetration of the impurity.

11,489 METHOD OF PRODUCING A SEMICONDUCTOR

DEVICE OF THE JUNCTION TYPE by R. Emeis (Siemens AG); U.S. Pat. 3,009,840, Issued Nov. 21, 1961

A technique for simultaneously forming a p-n junction in n-type Si and attaching an ohmic contact to the p-type region is described. Boron powder is sprinkled on an Au foil placed on the surface of a Si wafer and the assembly is heated for 5 to 10 minutes at between 400° and 500°C while a pressure of about 1 to 2 kg/cm² is applied. The quantity of B powder distributed on the surface is not critical. An apparatus for performing the alloying operation is described. Because its distribution coefficient is almost one, the B is contained in the Si which solidifies first. An Au-Si eutectic is formed on the recrystallized p-type region. Any excess B appears on the surface and can be wiped off.

Impurity Gettering during Diffusion - See 11,289 and 11,290

11,490 SEMICONDUCTIVE DEVICE COMPRISING P-I-N CONDUCTIVITY LAYERS by A. Uhlir, Jr. (Bell Labs.); U.S. Pat. 3,008,089, Issued Nov. 7, 1961

The fabrication of diffused p-n and p-i-n junction diodes for use at high frequencies is described. A number of very small diameter holes are drilled into one surface of a slice of intrinsic semiconductor. A p-type impurity is diffused into one surface and an n-type impurity into the other surface. By controlling the diffusion either a p-n or a p-i-n junction is formed at the bottom of each hole. The slice is then cut up into several diodes. The very small junction area permits operation at high frequencies while the bulk of the semiconductor facilitates handling the device and applying electrodes to it. The geometry of the device reduces the possibility of surface breakdown. A multistage parametric amplifier constructed by fabricating a number of diodes in single piece of semiconductor is described. In the multistage amplifier the high conductivity surface layers connecting the diodes serve as the two conductors and the intrinsic material serves as the dielectric of a two-conductor transmission line.

11,491 JUNCTION DIODES ON GALLIUM ARSENIDE DENDRITES by N. A. Jordan (Westinghouse); J. Electrochem. Soc., Vol. 108, p. 263C (A), Dec. 1961

The feasibility of making useful p-n junction diodes on dendritic GaAs was discussed. Junction diodes have been made by alloying a p-type impurity on n-type GaAs dendrites as the substrate. The dendrites are grown in the [211] direction and the junctions are formed on the (111) plane. Dendrites with a net impurity concentration varying from 5×10^{16} to 5×10^{18} atoms per cc have been used. The characteristics of these diodes (forward and reverse currents, capacitance, etc.) have been evaluated in a range of temperatures from 77° to 350°K and under two different ambient conditions. Units have been made with breakdown voltages above 70 v.

Masking Techniques for Diffused Planar Diode Fabrication - See 11,504

11,492 SEMICONDUCTOR DEVICES by D. Boswell and J. Ewels (GE Ltd.); U.S. Pat. 2,999,194, Issued Sept. 5, 1961

The construction of a semiconductor rectifier, with provisions for convenient assembly and heat dissipation, is described. The device consists of a Si wafer mounted in an hermetically sealed (cold pressure welded) envelope. Methods of securing the wafer, of providing contact to a second region of the semiconductor, and of etching and sealing the rectifier are discussed.

DIODES (Cont'd)

Device Packaging - See 11,507

Metallic Desiccants for Use in Diode Packages - See 11,509

TRANSISTORS

11,493 GERMANIUM TRANSISTORS FOR OPERATION ABOVE 1 kMc by J. T. Nelson and A. G. Foyt (Bell Labs.); Proc. 1961 Electron Devices Meeting, p. 16(A), Oct. 26-28, 1961

Two diffused base Ge transistors, designed for use as common base amplifiers above 1 kMc, were described. Both are coaxially encapsulated p-n-p structures in epitaxial Ge with base layer widths of 0.3 microns. The smaller device has emitter and base stripes of 7.5×37.5 microns with 4-microns separation. A power output of 20 mw at 1 kMc and 13 mw at 2 kMc has been obtained with a bias power of 60 mw and an input drive of 2 mw. Insertion gain at 1 kMc for the transistor with tuned input and output and no external feedback is 17 db with a reverse transfer through the device and tuning elements of -16 db. An amplifier with one transistor has provided 12 db of gain at a center frequency of 1.9 kMc with a 3 db bandwidth of 200 Mc. The power unit is similar in structure with enlarged stripes and a beryllium oxide insulator on the collector terminal to provide greater heat transfer. Small signal insertion gain for this device is 13 db at 1 kMc. A power output of 225 mw at 1 kMc has been obtained with a circuit gain of 6 db and a collector efficiency of 30 per cent.

11,494 SILICON SWITCHING TRANSISTOR [in German] by W. Munch and H. Salow (Fernmeldetech. Zentralamt, Darmstadt); Nachrichtentech. Z., Vol. 15, pp. 436-440, Sept. 1961

The design of a Si switching transistor with storage properties is discussed. The fabrication of the device and the switching properties obtained so far are described. The input characteristic of the switching transistor can be varied within wide limits by a suitable choice of the specific resistivity of the material and the geometrical dimensions, and the switching rate can be made high while the rise time as well as the decay time of a switching signal are held very small.

11,495 A GERMANIUM ULTRA HIGH SPEED SWITCHING TRANSISTOR by D. Granberry, D. D. Martin, E. Orris, and C. M. Chang (Texas Instr.); Proc. 1961 Electron Devices Meeting, p. 24(A), Oct. 26-28, 1961

A mesa type Ge switching transistor, designed for switching rates up to 100 M in a saturating circuit, was described. The device features a unity-gain frequency of 1.5-4 kMc, collector and emitter depletion capacitance of 1 pf each, and operation at a collector current of up to 50 ma. Certain switching times have been as low as 5 nsec total. The current gain at a collector current of 50 ma is usually ≥ 30 and collector breakdown voltage ≥ 10 v. Epitaxial pp^+ material is used, resulting in low collector saturation voltage and low storage time and in a relatively constant f_t up to a collector current of 50 ma. The diffused n-type base layer is $1/4 - 1/2$ micron thick. The rectangular emitter stripe, $0.0015" \times 0.0005"$, penetrates $1/8$ micron into the diffused base layer. A new header achieves low inductance and capacitance, and is well adapted to strip line or other circuit techniques. Design calculations were presented.

11,496 HIGH FREQUENCY TRANSISTOR by D. Q. Fuller (Pye); U.S. Pat. 3,007,091, Issued Oct. 31, 1961

A technique for improving the frequency response and the current gain characteristics of drift transistors is described. A second base electrode is applied to the collector side of the base region and a voltage V , so poled that carriers are accelerated toward the collector, is applied between the base electrodes. The second electrode extends up to the collector junction but does not make contact with it. When V is large, a space charge is created near the collector junction. A signal applied to the auxiliary electrode controls the current to the collector from the immediate vicinity of the junction, thus producing a very high frequency response. Under some conditions the device exhibits an alpha greater than unity.

11,497 SEMICONDUCTOR DEVICES AND METHOD OF MAKING SAME by R. S. Schwartz and B. N. Slade (IBM); U. S. Pat. 3,001,895, Issued Sept. 26, 1961

The fabrication of high frequency diffused junction drift transistors is described. A thin diffused base layer is first formed on one surface of the wafer. The wafer and the diffused layer are of opposite conductivity types. An alloy containing both p- and n-type impurities is then alloyed to the diffused layer. The impurities are so chosen that the impurity of the same type as the diffused layer has a higher diffusion coefficient and a lower segregation coefficient than the other type impurity. The alloying process produces an emitter region of the original wafer conductivity and a base layer which is much wider in the vicinity of the emitter than elsewhere. The resulting device has a high base to collector current amplification factor, a very low "on" resistance, a high avalanche breakdown voltage, a very low storage time, a specified emitter to base breakdown voltage, and a high "punch through" voltage. Specific examples of the process are given.

11,498 AN INTRODUCTION TO THE AVALANCHE TRANSISTOR by C. D. Root and E. Adler (Raytheon); Semicon. Prod., Vol. 4, pp. 24-28, July 1961

A detailed description of the processes taking place within the avalanche transistor, some simple circuits incorporating the avalanche transistor and some aspects of the avalanche transistor's negative-resistance property are discussed. Applications in an emitter-follower circuit, as a relaxation oscillator and as a punch-through oscillator are included. Emphasis is placed on an application as a pulse generator, with predicted megacycle repetition rates of 50 volt pulses, and fractional nanosecond rise and fall times. Noise considerations and cost reductions due to the fusion alloy fabrication process are mentioned briefly.

11,499 THERMAL PROBLEMS OF TRANSISTORS [in German] by H. J. Thuy (Telefunken, Hellbronn); Elektron. Rundschau, Vol. 15, No. 2, pp. 61-65, 1961

Various methods of measuring the thermal internal resistance are discussed and several test circuits are described. Measuring the heat dissipation resistance of cooling surfaces, determination of the thermal time constant of transistors, and representation of the thermal inertia by capacitances in an equivalent circuit are explained. The runaway effect and criteria denoting thermal stability of the transistor in the circuit are discussed.

11,500 METHOD OF MANUFACTURING SEMICONDUCTOR DEVICES by J. J. A. P. van Amstel (Philips); U. S. Pat.

3,002,864, Issued Oct. 3, 1961

A technique for alloying rectifying contacts to Ge wafers is described. The wafer is first heated in an oxidizing atmosphere at a temperature between 200° and 500°C and then cooled. The alloying metal is then made to wet the Ge by heating the wafer and pellet at 300°C in a hydrogen atmosphere containing a flux which forms a halide with either the Ge or the metal. The temperature is then raised to 600°C to alloy the wetted metal. Alloyed contacts are made to both sides of the wafer by means of a jig containing two apertures. The method is illustrated by alloying In to n-type Ge using HCl vapor as the flux. The technique can also be used with pure or doped Bi, Pb, or Sn with fluxes such as pyridine hydrochloride or indium chloride.

Impurity Gettering during Diffusion - See 11,289 and 11,290

11,501 A TRANSISTOR UTILIZING AN EPITAXIALLY GROWN BASE AND COLLECTOR REGION by J. K. Clifton and H. M. Robertson (Motorola); Proc. 1961 Electron Devices Meeting, pp. 20 (A), Oct. 26-28, 1961

The possible advantages of a completely grown epitaxial structure were discussed. This structure is theoretically achievable by means of control of the impurity concentration during growth. An attempt at a partial answer by growing the collector and base region and then diffusing in the emitter was reported. This approach has the possible advantage of eliminating the long base diffusion which is required in the conventional epitaxial structure. Also, it provides a considerable amount of information about the properties of grown junctions and the state of crystalline perfection in the base region. These "grown base" devices are compared with the conventional high performance double-diffused epitaxial device, 2N834. The effects of base doping and geometry were discussed.

11,502 TRANSISTOR AND METHOD OF MAKING SAME by E. N. Murad (Orbitec); U.S. Pat. 3,001,112, Issued Sept. 19, 1961

A method of producing high frequency junction transistors with an extremely short diffusion path or base width is described. The collector and base electrodes are first bonded to the transistor material. The position of the emitter electrode is then adjusted by means of a control circuit which monitors the collector-to-emitter current gain. When the control circuit indicates the optimum position, the emitter electrode is bonded by resistance heating. This results in a high frequency transistor with low collector-to-base capacitance. Material specifications and diffusion temperatures are suggested.

11,503 TRANSISTORS by J. I. Pankove (RCA); U.S. Pat. 3,005,132, Issued Oct. 17, 1961

The fabrication of Ge alloy junction transistors which have high current gain, α , is described. High α is achieved by utilizing a collector whose diameter is much larger than that of the emitter. Data obtained on several transistors with various emitter and collector diameters are presented. For example, a transistor with a collector diameter of 0.015 in and an emitter diameter of 0.045 in has an α of 0.18, while a transistor with a collector diameter of 0.125 in and an emitter diameter of 0.015 in has an α of 0.98.

11,504 PLANAR GERMANIUM DIODES AND TRANSISTORS

by K. Simonyan and P. Constantakes (Genl. Instr.); Proc. 1961 Electron Devices Meeting, pp. 20-22 (A), Oct. 26-28, 1961

A diffusion-mask technique used to produce Ge planar diodes and p-n-p transistors was described. This preferential masking is effective for various p- and n-type dopants at different concentration levels and diffusion lengths. The characteristics of the planar and its equivalent mesa structure were compared. All the surface dependent parameters have shown improvement over the mesa units. Also, a very narrow distribution of these parameters has been observed. Units fabricated by this technique have higher reliability at ambient as well as elevated temperatures than equivalent mesa units. Life stability of the device is very satisfactory. The planar structure has apparently overcome the sensitivity to ambient cycling which etched Ge junctions possess.

11,505 SEMICONDUCTOR DEVICES by W. M. Webster, Jr. (RCA); U.S. Pat. 3,006,791, Issued Oct. 31, 1961

The preparation of high frequency diffused transistors which can handle currents as high as 20 a and which have collector breakdown voltages in excess of 400 v is described. A mask is applied to one surface of a wafer and an impurity of the opposite type is diffused into the unmasked regions. The mask is removed and a second diffusion with the same type impurity is carried out. The conditions of this second diffusion are so controlled that a thin, high conductivity region is formed at the semiconductor surface. If the starting material is p-type, the resulting structure is $n^+-n-p-n^+$, with the n^+-n region serving as the collector. The diffused material on the edges of the wafer is removed and the emitter n^+ region is made into the shape of a mesa to permit application of the base contact.

11,506 SEMICONDUCTOR DEVICES by T. W. Cooper (Hughes Aircraft); U.S. Pat. 3,007,092, Issued Oct. 31, 1961

A technique for attaching an electrode to a semiconductor surface or to an alloyed junction which does not require abrading the semiconductor surface or the use of chemical fluxes is described. A layer of a metal which has a low solubility in and can be wet by a solder is first applied to the desired area of contact, e.g., by evaporation. An electrode coated with the solder is then brought into contact with the plated area and the assembly is heated, causing alloying between the solder and the metallic layer.

Soldered Leads for Use in Transistors - See 11,326

11,507 SEMICONDUCTOR DEVICE ASSEMBLIES by C. W. Mueller (RCA); U.S. Pat. 3,001,113, Issued Sept. 19, 1961

An improved hermetically sealed enclosure for semiconductor devices is described. The unit is sealed without employing high temperatures and pressures, and the resultant enclosure is of favorable size and weight such that the high frequency performance of the unit does not suffer. The enclosure is especially adapted for etching and inspection of the semiconductor unit prior to final sealing. Techniques of manufacturing the unit are described and preferred materials are suggested.

11,508 HOLDERS FOR ELECTRICAL DEVICES by M. N. Glickman; U.S. Pat. 2,999,964, Issued Sept. 12, 1961

A miniaturized package for junction transistors is described. The package consists of two concentric, electrically-insulated metal rings between metal top and bottom plates. The bottom plate serves as one connection to the device which is soldered to it.

TRANSISTORS (Cont'd)

Contacts to the other regions of the device are made by means of leads between the device and the inward projections on each ring. The top plate is welded to the upper ring. Exterior projections from the rings and the bottom plate permit electrical connection to the device.

11,509 SEMI-CONDUCTOR by A. J. King; U.S. Pat. 3,007,089, Issued Oct. 31, 1961

The use of a metallic desiccant in a hermetically-sealed transistor or diode is described. The desiccant is bonded, either by pressure or by heat, onto the inner surface of the device container. The desiccant may be either K, Na, Li, Ba, Sr, or Ca or an alloy of two of these metals. The desiccant reacts with moisture in the container to form very stable compounds. Li, for example, reacts with water to form Li_2O and LiO_4 , and with O_2 to form Li_2O .

11,510 FIELD EFFECT TRANSISTOR by R. N. Noyce (Clevite); U.S. Pat. 3,010,033, Issued Nov. 21, 1961

A high frequency field effect transistor which can be grounded for RF signals and which exhibits small input and output capacitances is described. The device is fabricated on a high resistivity wafer of the same conductivity type as the gate. The channel thickness is made very small to permit operation at high frequencies. By applying a reverse bias to the junction between the high resistivity region and the channel, the high resistivity region may be grounded at RF frequencies.

11,511 STRUCTURES FOR A FIELD-EFFECT TRANSISTOR by M. A. Chappey; U.S. Pat. 3,001,111, Issued Sept. 19, 1961

A unipolar field-effect transistor for VHF is described. The length of the channel subjected to the field-effect is reduced to the thickness of the metallic deposit which constitutes the gate. The unipolar structure is obtained from a support of semiconductive material on which the gate electrode, produced by vacuum deposition techniques, takes the form of two parallel grooves containing a semiconductive alloy which is highly doped with suitable impurities. The geometry of the gate may employ either the cloud form (e.g., concentric annular rings) or the open form (e.g., parallel spirals). The advantage of the latter is that it is possible to regulate the length of the gate by subsequent metallic deposits in accordance with measuring and control apparatus.

PHOTODEVICES

11,512 ANALYSIS OF PHOTOJUNCTIONS FORMED BY DIFFUSING COPPER INTO INSULATING CADMIUM SULFIDE CRYSTALS by R. R. Bockemuehl, J. E. Kaupila, and D. S. Eddy (Genl. Motors Res. Labs.); J. Appl. Phys., Vol. 32, pp. 1324-1330, July 1961

A study of the observed photovoltaic, photorectification, and field effect modulation properties of junctions formed by diffusing copper into photoconductive, dark-insulating CdS crystals is presented. The study shows that two potential barriers are produced, one at the surface, the other in the crystal bulk. A transition from a double space charge dipole to a single separated dipole occurs at a reverse bias of less than 1 v. A corresponding transition from a primary to a secondary photocurrent process results. Values for the drift mobility of holes

ranging from 10^{-5} to $10^{-2} \text{ cm}^2/\text{v-sec}$ were derived from field effect measurements and found to be proportional to illumination intensity at the infrared quenching wave lengths.

11,513 LONG-WAVELENGTH PHOTOEFFECT IN MERCURY SELENIDE by M. D. Blue, J. H. Garfunkel, and P. W. Kruse (Honeywell Res. Ctr.); J. Opt. Soc. Am., Vol. 41, pp. 1408-1410, Dec. 1961

An infrared detector which uses a photoeffect in HgSe and which responds from the visible to 15μ is described. Although the detector construction and sample geometry are similar to that employed in the photoelectromagnetic (PEM) effect, performance differs from that expected of the PEM effect. The spectral response for constant power input per unit wave length interval peaks in the visible and is wave length independent in the interval from 3 to 15μ . The frequency response indicates a detector response time of $150 \mu\text{sec}$. A thermal response mechanism is proposed.

11,514 A LOW ATOMIC NUMBER SOLID-STATE RADIATION DETECTOR by H. J. Fullbright, L. Blanks, and H. Rohrer (Emory U.); Bull. Am. Phys. Soc., Vol. 6, Ser. II, p. 456 (A), Nov. 24, 1961

A solid-state gamma and x-radiation detector was discussed. The detecting element is an anthracene crystal 1.27 cm in diameter and 0.2 cm thick. The crystal is mounted in a Lucite sandwich-type holder, and the electrodes are of water-base Aquadag. The geometric arrangement of the electrodes is such that surface conduction of the crystal and bulk conduction of the holder are not measured and the true volume photoconductivity of the anthracene is utilized. The entire device is shielded so as to prevent the measurement of air ionization. The illumination of the cell is obtained from a 220-kv, x-ray generator and from a small source of Co^{60} . The photocurrent is on the order of 4×10^{-13} amp per roentgen, which is in range of the currents obtained with ultraviolet illumination. The wave length, intensity, and voltage dependences of the current were examined. A description of the cell and the system was given. A brief summary of the results and possible applications of this type of dosimeter were also presented.

CdS Spectrophotometers - See 11,455

11,515 SEMICONDUCTOR JUNCTIONS AS POSITIONAL INDICATORS OF RADIATION by L. W. Davies (Amalgamated Wireless Ltd., Austl.); Proc. IRE, Austl., Vol. 22, pp. 509-512, Aug. 1961

A theoretical interpretation of lateral photovoltage generation in the plane of a non-uniformly illuminated semiconductor junction is presented. By employing two p-n junctions in a single crystal of semiconductor material, such as a pair of alloyed rectifying contacts formed on one side of a thin slice, it is possible to indicate the position of a small irradiated area between the contacts. The difference in photovoltage generated at each of the junctions is proportional to the position of the incident radiation center. The devices may be used with near infrared radiation since the incident photons need only have energies greater than the band-gap energy of the semiconductor.

Ge Grain Boundary Photocells - See 11,429

Phosphor Screens of ZnS:Ag - See 11,452

THERMAL DEVICES

11,516 TRANSIENT EFFECTS IN PELTIER COOLERS by A. D. Reich, T. Arai, and J. R. Madigan (Borg-Warner); *Bull. Am. Phys. Soc.*, Vol. 6, p. 437(A), Nov. 24, 1961

Calculations of transient effects in Peltier coolers, made under the assumption that the Peltier voltage is temperature dependent, were discussed. There is a more severe restriction on the size of the thermal cold spikes obtained for arbitrarily large currents than when the Peltier voltage is assumed to be temperature dependent. The thermal conductivity of some Bi_2Te_3 alloys was determined. The agreement with other methods is surprisingly good since the transient response for this model could be only qualitatively correct.

11,517 FORCED CYCLED COOLING OF THERMAL DETECTORS by E. Speyer and E. Brigmanis (Am. Mch. and Fdy.); *Opt. Soc. Am.*, Vol. 51, pp. 1417-1421, Dec. 1961

The forced cycled cooling of thermal detectors is discussed. Recovery time of a thermal detector can be reduced to a negligible fraction of the chopping cycle by cooling the chopping blade. The possible gains in chopping frequency and responsivity are analyzed and calculated for the case of square-wave chopping. Disadvantages, such as distortion of the detector output waveform, are also analyzed.

Metallic Thin Film Resistor Thermometers - See 11,477

MAGNETIC DEVICES

11,518 MAGNETIC AMPLIFIERS by G. F. Pittman, Jr. and O. Decker (Westinghouse); *Handbook Automn., Computatn., and Control*, Vol. 3, J. Wiley and Sons, 1961, pp. 25-01 to 25-39

The properties, design and applications of magnetic amplifier circuits are described. The basic principles of saturable reactors are first presented, and the fundamental equations governing the circuit are discussed. Core materials and core construction techniques are described, factors influencing the choice of rectifiers for use with solid-state circuits are indicated. Design procedures for load circuit design and core site selection are given, and a sample control circuit design is illustrated. The discussion is concluded by the presentation of commonly used magnetic circuits including both half-wave and full-wave single-ended and push-pull circuits, polarity- and phase-reversal circuits, and Ramey logic circuits.

11,519 THE SHEARING OF THE INITIAL PERMEABILITY WITH INTERLEAVED LAMINATION STACKS [in German] by Brenner and F. Pfeifer (Vacuumschmelze); *Entwicklungsber.* and H., Vol. 24, pp. 82-96, June 1961

The theory of the shearing of the initial low signal permeability of magnetic cores stacked from punched laminations is presented. Relatively simple relations for the reluctances of individual sections of the flux path which allow a calculation of the shearing with nearly all core and lamination shapes, respectively, are obtained. Comprehensive experimental tests of the formulas revealed very close agreement with the theory. The sheared initial permeability is calculated as a function of the shearing length for all standard lamination sizes and for a number of other often-used laminations. These calculations are presented in diagrams for practical use.

11,520 HOW MAGNETIC MATERIALS BEHAVE AT NANO-SECOND PULSE WIDTHS by G. A. Reeser (U. California); *Electronics*, Vol. 34, pp. 72-75, Sept. 8, 1961

A test procedure for tape-wound and ferrite magnetic cores operated at a 30-nanosecond pulse width is described. A block diagram and appropriate schematic are given for the test method used. Typical waveforms of drive current and discussion of the special circuitry involved are included. With tape-wound cores, the pulse μ improves with thinner laminations but stacking factors enter into consideration and the effective magnetic characteristics are maximum for 1/2- to 1/4-mil tapes. Better ferrites are comparable to the 1/2- and 1/4-mil tape-wound cores both having an effective pulse μ of about 500. The only advantage of tape-wound cores at 30-nanosecond pulse width is higher saturation. Data on several cores are presented graphically and may be extrapolated to large cores for 0.1-megawatt operation. Limitations of the data lie in the tolerances of magnetic properties for a material. The excitation losses, pulse μ and current waveforms are useful as tools in the design of magnetic devices.

Ferrite Materials for High Frequency Cores - See 11,310

Cd-Ni Ferrites for Magnetic Cores - See 11,310

Low Noise Magnetic Films - See 11,304

11,521 SQUARE LOOP FERRITES by E. Albers-Schoenberg (Steatite Res.); U.S. Pat. 3,007,875, Issued Nov. 7, 1961

The use of a small amount of silica (between 0.3 and 4 mol per cent) to improve the characteristics of Mg-Mn ferrite cores is discussed. The addition of silica reduces the switching and peaking times and increases the signal-to-noise ratio and the amplitude of the maximum allowable half-selecting field of the cores. For example, a core prepared with 33.5 mol per cent MgO , 33.0 mol per cent MnO , and 33.5 mol per cent Fe_2O_3 exhibited a peaking time of 0.48 μsec , a switching time of 1.21 μsec , a signal-to-noise ratio of 3.88, and a maximum allowable half-selecting field of 1.05 amp and 1.52 oe. The values of the same parameters exhibited by a core of the same composition, but with 0.65 mol per cent silica added, were: 0.31 μsec , 0.79 μsec , 4.68, and 1.75 amp and 2.56 oe, respectively.

11,522 METHOD FOR INCREASING THE EFFECTIVE PERMEABILITY OF MANGANESE FERRITES by L. J. Brady (Kearfott); U.S. Pat. 3,003,967, Issued Oct. 10, 1961

A technique for removing the oxide coating from a sintered manganese ferrite, thereby increasing its permeability, is described. The oxide coating is removed by inserting the ferrite in a strong acid for a time sufficient to dissolve the oxide coating. The process is inexpensive, since the acid need not be pure. In one example cited, the permeability of a manganese ferrite was increased from 1860 to 2830 by immersing it in a solution of concentrated HCl for one hour at room temperature. The process is particularly useful with ferrites of complex shapes.

Permalloy Alloys for Switching Applications - See 11,317

Low Magnetic Moment Garnets for Use in Switching Devices - See 11,303

Ferrite Material for Permanent Magnets - See 11,316

11,523 THERMODYNAMICS AND STATISTICAL MECHANICS OF A THREE-LEVEL MASER by W. A. Barker (Argonne Natl. Labs.); Phys. Rev., Vol. 124, pp. 124-128, Oct. 1, 1961

The three "spin" states of a maser are discussed. The states are treated as individual chemical species and it is assumed that these three species are in thermal equilibrium with the lattice at temperature T , but that they are not necessarily in chemical equilibrium with one another. The principle of minimum entropy production is used to derive an equation of reaction equilibrium from which the steady state behavior of the system with a microwave pump may be completely described. In addition to the population distribution, which is in agreement in first order with the results obtained by solving the rate equations, explicit expressions for the internal energy, heat capacity, and entropy are obtained. The calculations are extended to include spontaneous emission and cross-relaxation as well as the usual thermal relaxation mechanisms.

11,524 CROSS-RELAXATION EFFECTS IN RUBY L-BAND (1440 Mc) MASER AT LOW MAGNETIC FIELDS by G. S. Bogle and F. F. Gardner (CSIRO); Austl. J. Phys., Vol. 14, pp. 381-402, Sept. 1961

The reversals of maser behavior which occur in ruby at low fields on cooling from 80° to 4°K are explained. The explanation is in terms of cross-relaxation transitions (resonant interchanges of energy between neighboring paramagnetic ions). For an angle of 29° between the magnetic field and the crystal axis, a cross-relaxation process has been demonstrated which involves groups of three ions and has a transition probability of 700 ± 100 per second in 0.013 per cent ruby. The profile of the cross-relaxation resonance has a half-width of 190 ± 30 Mc at half-intensity, and has an approximately Gaussian shape. It should be possible to obtain useful low-field L-band maser action at 4°K by pumping ν_{41} with the magnetic field nearly perpendicular to the crystal axis, and also at 80°K using a concentration ten times higher, i.e., 0.13 per cent.

11,525 GIANT OPTICAL PULSATIONS FROM RUBY by F. J. McClung and R. W. Hellworth (Hughes Res. Labs.); Bull. Am. Phys. Soc., Vol. 6, p. 414(A), Nov. 24, 1961

Observations of giant pulses of optical maser radiation which are several orders of magnitude larger than the commonly observed spontaneous pulses were reported. The pulses were produced by varying the effective reflectivity of the reflecting surfaces at the ends of the ruby rod through a kerr-cell switching technique. The measured pulse characteristics were found to be in agreement with theoretical predictions.

11,526 THEORETICAL CONSIDERATIONS OF OPTICAL MASER RADIATION. I. THE RESONANT MODE STRUCTURE OF A RUBY FABRY-PEROT CAVITY by M. Resnikoff and Y. H. Pao (U. Chicago); Bull. Am. Phys. Soc., Vol. 6, p. 414(A), Nov. 24, 1961

The electromagnetic resonant mode structures of ruby rods were discussed. Total internal reflection at a bounded surface is accompanied by a loss of energy from the internal modes. Analytical expressions for the modes, the rate of energy loss for each mode, and the density of modes as a function of frequency and propagation vector were given.

11,527 THE MASER AMPLIFIER AS A PRACTICAL MICROWAVE

COMPONENT by F. E. Goodwin, J. E. Kiefer, and G. E. Moss (Hughes Res. Labs.); 1961 IRE Intl. Conv. Rec., Vol. 9, Part 3, pp. 76-80

Microwave maser amplifiers with typical noise temperatures near 10°K and offering substantially improved performance in a variety of systems, e.g., satellite communications, long-range radar, are discussed. Until recently, the complexity and bulkiness of maser amplifiers has seriously restricted their usefulness. Through unconventional packaging, single-port and traveling-wave X-band masers, together with their magnets, circulators and isolators, have been developed to fit within a miniature dewar less than 14 inches long, weighing less than 12 pounds. These masers will operate 20 hours in any position on one charge of helium. The cryogenic technology is being further refined to allow the use of a self-contained miniature helium refrigerator weighing 35 pounds.

Tungstate Paramagnetic Crystals for Use in Masers - See 11,321

BASIC SOLID STATE DEVICE CIRCUITS

GENERAL

11,528 NEW METHOD OF COMPENSATING NETWORK DESIGN FOR FEEDBACK SYSTEMS by H. Amemiya (RCA); IRE Trans., Vol. AC-6, pp. 360-361 (L), Sept. 1961

A new design method, using a Nyquist plot as its basis, which simplifies the design of compensating networks in feedback control systems is described. The basis of the new approach is that the $G_o/G_c(j\omega)$ plot has a characteristic that any point on this plot can be brought to G_o through use of a compensating network $G_c(j\omega)$. The plots of $G_s(j\omega)$ and $G_o/G_c(j\omega)$ have two intersecting points, a and a' , either of which can be brought to G_o by the compensating network. The resultant $G_s(j\omega)G_c(j\omega)$ plot passes through the point G_o when the $G_s(j\omega)$ plot and the $G_o/G_c(j\omega)$ plot intersect at point a at the same frequency. The procedure is to adjust $G_c(j\omega)$ so that point a represents the same frequency for this function as for $G_s(j\omega)$. Phase-lag and phase-lead compensating networks are illustrated.

11,529 ANALYZING NON-LINEAR CIRCUITS by V. Petrucci (Am. Mch. and Fdy.); Electronic Ind., Vol. 20, pp. 112-117, Oct. 1961

A graphic method for solving nonlinear circuits is discussed. Volt-ampere characteristics of "black box" elements are obtained by "interrogating" the element with a voltage and determining the current that flows. A superposition method of handling the volt-ampere characteristics of two or more elements is given. Interrogation methods for solving transistor amplifier configurations by employing their characteristic curves are illustrated. The technique allows designers to get a graphical picture of the action of a component under chosen conditions which makes it easier to modify parameters by visual observation of the graphical parameters.

11,530 TECHNIQUES OF MICROMINIATURIZATION by D. H. Roberts and D. S. Cambell (Caswell Res. Lab.); J. Brit.

IRE, Vol. 22, pp. 281-292, Oct. 1961

Two approaches to micro-circuits are described and their merits are discussed. In the case of thin film circuits it is shown that resistors and capacitors can be made in conjunction with one another over ranges between 1Ω to $10M\Omega$ and $0.03\mu f/cm^2$ to $0.12\mu f/cm^2$. A discussion of manufacturing techniques is given. Problems yet to be solved are the construction of inductances and variable R and C. The case of integrated single crystal circuits offers an alternative approach to microminiaturization. Since many passive elements can be made using the same well established solid-state diffusion techniques, the method also offers ultimate simplicity and reduced cost. Methods of constructing single crystal devices are discussed and the employment of p-n junctions as passive and active elements in solid circuits is illustrated by several examples. A discussion of low temperature devices is included. The developments in microminiaturization are important for use in space vehicles by virtue of the reduction in size and weight and by increased reliability.

11,531 A STITCH-WIRING PROCESS FOR MINIATURIZED COMMUNICATIONS ELECTRONICS by J. M. Coffin and L. Johnson (Lenkurt Elec. Co.); Electrical Engrg., Vol. 80, pp. 849-853, Nov. 1961

A recently developed manufacturing process known as stitched wiring which permits economical fabrication of circuits by automatic or semiautomatic methods is described. An insulated board is used, as in printed or etched wiring. The basic board is black XP phenolic. The process dispenses with laminated copper foil for the wiring, and substitutes tin-coated bronze staples and "automatic hand wiring" at appropriate locations. Each staple becomes the termination for one or more nearby components, and for bare-wire connections to other terminations of this type. Detailed descriptions of the entire manufacturing process is given including close-up photographs of machinery heads. The process is economical and long term preservation of equipment employing the stitched-wiring technique confirms that reliability and serviceability are excellent.

11,532 APPLYING DOT COMPONENTS TO ELECTRONIC PACKAGING by J. R. Goodykointz (Space Tech. Labs.), and R. C. Frank (Douglas Aircraft); Electronic Ind., Vol. 20, pp. 88-92, Oct. 1961

A dot packaging system which uses discrete, individual components is described. Adequate design flexibility for new systems is retained by this method of keeping components as basic circuit elements. The dot system standardizes on a disc-shaped component 0.030 in thick. The disc diameter may vary. The ends of the disc form the component terminals. Availability of dot component sources is constantly improving. Methods of assembly, thermal aspects, and manufacturability of circuits and unit assemblies employing dot components are described.

11,533 A SURVEY OF THIN-FILM TECHNOLOGY by J. Watkins (Asst. Ed. Electronic Ind.); Electronic Ind., Vol. 20, pp. 102-108, Oct. 1961

Methods of growing metallic and crystalline structures for electronic applications are discussed. The manufacturing techniques and design considerations for thin film resistors, conductors, inductors, photovoltaic cells, and thin film superconductors are described. The latter exhibits a tunneling effect when two metal thin films are separated by a thin insulating layer. From

this phenomena it may be possible to produce new forms of diodes, switches, triodes, resistors or capacitors. A new means for achieving electronic amplification based on thin films, "Metal Interface Amplifier" (MIA) is described. Electron current through the amplifier metal base is the flow of majority carriers so MIA cannot be classed as a transistor. A brief description of sputtering (the result of a glow discharge between an inert anode and a bombarded cathode of the desired conducting material) is given. Thin film techniques may result in low cost, reliable circuitry and microminiaturization.

11,534 LIMITATIONS OF FILM-TYPE MICROSYSTEM CIRCUITS CONSISTING OF RESISTIVE AND CAPACITATIVE LAYERS by W. W. Happ and G. C. Riddle (Lockheed); 1961 IRE Intl. Conv. Rec., pp. 141-165

A study of the effects of various factors on the limitations of a microsystem consisting of resistive and capacitive layers is presented. The essential limitations are: 1) a lower limit of resistance, ~ 1 ohm due to ohmic contacts; 2) an upper limit of resistance, ~ 0.1 megohm due to film stability; 3) a lower limit due to interelectrode capacitance, ~ 1 pf; and 4) an upper limit of capacitance due to area limitation, ~ 10 μ mf. Material properties are examined in terms of device design objective. Recommendation and design criteria for microsystem circuits are presented in tabular form, with several illustrative examples.

11,535 HIGH DENSITY ELECTRONIC PACKAGING-THERMAL DESIGN by C. Kadlec and S. Francis (Sippican); Electronic Design, Vol. 9, pp. 44-47, Nov. 8, 1961

Design steps involved in achieving proper thermal performance in tightly packed microminiature electronic assemblies are outlined. In High-Density Electronic Packaging (HDEP) components are encapsulated in epoxy compounds of known thermal characteristics. Heat is removed from the components by conduction, which is not affected by altitude or surface conditions. Simple shapes and simple heat exchangers are employed. As a result, the thermal performance of the design can be predicted and the excessive component temperatures can be eliminated at the design stage. An information flow chart showing the relationship between package demands and thermal considerations is given. Application of an aluminum cooling foil to remove heat from a circuit module is described. Arrangements of components to minimize temperature differences between components are discussed. In cases where the component heat to be removed is not too excessive metallic conductors need not be employed and a potting compound of a suitable thermal conductivity can be selected. A table of thermal characteristics of several encapsulating compounds is given.

AMPLIFIERS

11,536 A STUDY OF GAIN CONTROL IN AUDIO AMPLIFIERS by J. Heinchon (Philco); Semicon. Prod., Vol. 4, pp. 40-43, Oct. 1961

Different methods of gain control which can be used with an AGC circuit are discussed. The methods include varying the operating point and using diodes or transistors as resistances which are varied by AGC voltages. The most practical means of obtaining the desired control in a LF amplifier is by use of a feedback transistor. The required parameters for selection of the transistor are given. A transistor providing approximately 30 db of AGC range with little change in response is described. Several other AGC circuits are also discussed.

AMPLIFIERS (Cont'd)

11,537 NOISE FIGURE AND STABILITY OF NEGATIVE CONDUCTANCE AMPLIFIERS by A. C. Macpherson (U.S. Naval Res. Lab.); Proc. IRE, Vol. 49, pp. 1314-1315(L), Aug. 1961

The over-all noise figure of a negative conductance preamplifier connected through an ideal transformer to a conventional receiver is investigated. Expressions of the lowest possible noise figure, attained theoretically at the verge of oscillation, and of the minimum noise figure (minimized with respect to an optimum value of the gain of the preamplifier) are obtained.

11,538 TUNNEL DIODE NOISE NOMOGRAPH by L. E. Dickens (Johns Hopkins U.); Electronic Ind., Vol. 20, pp. 110-112, Sept. 1961

A theoretical examination of the tunnel diode amplifier in relation to its noise figure is presented. The determination of noise is simplified, with the effects of frequency on this figure.

11,539 INTERPRETING TRANSISTOR NOISE PERFORMANCE by L. Calgagno and R. E. Hobson (Rheem); Electronic Ind., Vol. 20, pp. 109-112, Oct. 1961

The use of "Equivalent Noise Voltage" (ENV) referred to the input of an amplifier to evaluate transistor low-noise performance is discussed. Sources of transistor noise can be lumped into three terms: $1/f$ noise, shot noise, and thermal noise. The common figure of merit for an amplifier "Noise Factor" and its relation to ENV is discussed. Test circuits and sample measurements of ENV are given. The usefulness of ENV is that it provides the designer with a reference value for the minimum detectable signal.

11,540 HOW TO ANALYZE FEEDBACK IN TRANSISTOR AMPLIFIERS by J. C. Looney (Oregon State Coll.); Electronic Ind., Vol. 20, pp. 98-101, Sept. 1961

An analysis of the effects of positive feedback in a transistor amplifier is presented. The analysis is developed from root-locus and Bode plots made by an ESIAC computer. The performance of multi-loop feedback amplifiers can be improved by using positive feedback. Harmonic distortion and sensitivity to parameter variations can be reduced, signal-to-noise ratio can be increased and input and output impedance can be made either high or low. Using positive feedback in general results in a conditionally stable amplifier. A thorough analysis is needed to insure stable operation with adequate phase and gain margins.

Analysis of Amplifier Circuits - See 11,529

11,541 TRANSISTORS IN PREAMPLIFIERS FOR AMPLIDYNES AND MAGNETIC AMPLIFIERS [in German] by H. G. Lott; AEG Prog., No. 1, pp. 151-156, 1961

Continuously operating transistor dc amplifiers suitable for amplidynes and mmf controlled magnetic amplifiers are described, and the use of transistors in preamplifiers for rotary and magnetic amplifiers is discussed. With reset controlled magnetic amplifiers the transistor is operated in the reset circuit as a switch or nonlinear resistance. For magnetic amplifiers with relatively small power outputs the transistor is used as a leakage current controllable rectifier.

HF (1 kMc) Transistor Amplifiers - See 11,493

11,542 A STANDARD VIDEO AMPLIFIER MODULE USING TRANSISTORS by J. B. Potter (Postmaster Genl. Dept.); Proc. IRE, Austl., Vol. 22, pp. 512-513, Aug. 1961

A schematic diagram and specifications are given for a standard video amplifier circuit employing transistors. The amplifier supplies 0.7 vpp into 75 ohms, and has a nominal gain of 20 db. Thermal stability is good. The upper 3 db point occurs above 10 Mc. Two parallel connected transistors are employed in the emitter follower output stage to provide the 20 ma peak output current required to deal with all possible signal conditions. The module is readily assembled into complex systems.

11,543 NON-SATURATING TRANSISTOR PULSE AMPLIFIER by A. Feiner (Bell Labs.); U.S. Pat. 2,999,169, Issued Sept. 5, 1961

Circuits for transistor pulse amplifiers with high gain, high speed, and high sensitivity are presented. A transistor is employed in the feedback circuit of a common emitter pulse amplifier. The feedback transistor has its input connected so that it is normally inoperative. When the output of the amplifier reaches a predetermined level the feedback transistor becomes operative and introduces gain in the feedback circuit. The operation of the feedback circuit is thus more rapid and effective so that the transistor circuits may more nearly approach the saturation level without actually becoming saturated. Both the rise time and decay time of the amplifier are reduced in this manner. To improve stability of the pulse amplifier a grounded collector stage is employed to obtain the output voltage and the feedback voltages.

Pulse Amplifier - See 11,575

11,544 THE TRANSFLUXOR AS AN AMPLIFIER [in German] by F. Schreiber (Siemens and Halske); Entwicklungsber. S. and H., Vol. 24, pp. 5-16, June 1961

Findings showing that the transfluxor, in its original method of operation defined by Rajchman and Lo, is an integrating amplifier are presented. This fact is established by considering its storing capacity. The transfluxor has the property that any integration state and the corresponding output signal can be maintained indefinitely. This feature is equivalent to a zero lower cutoff frequency of the input signal offered for integration. Certain arrangements of the windings in the output circuit permit a loading with large power levels without possibility of a reaction on the input circuit. By proper suppression of the storage property the transfluxor may in principle be used in the design of a true amplifier with a characteristic suitable for flip-flop operation or with a linear characteristic. A calculation relating power gain and upper cutoff frequency shows that these true amplifiers in the form investigated produce no new advantages over good toroidal core amplifiers.

11,545 DEVELOPMENT OF C-BAND REACTANCE AMPLIFIER by J. C. Greene, J. Kliphuis, and J. J. Whelehan (Airborne Instr. Lab.); U.S. Gov. Res. Rep., Vol. 36, p. 27(A), July 20, 1961

The design, construction, and testing of three reactance amplifier models are discussed. One model was designed to use a GaAs point-contact diode and the other two were designed to use Si pill diodes. All three models met the specified performance requirements for room temperature operation. The model using two pill diodes in a balanced circuit configuration proved to be superior in all respects and the field-test models will be

based on this unit. The model using the point-contact diode should provide improved noise performance under refrigerated conditions.

11,546 PARAMETRIC AMPLIFICATION WITH A LOW-FREQUENCY PUMP by G. F. Montgomery (Nat'l. Bu. Stand.); Proc. IRE, Vol. 49, pp. 1214-1215 (L), July 1961

Regenerative signal amplification with a pump frequency lower than the signal frequency by a specified rational fraction is discussed. Odd denominators are chosen for the fraction since even denominators represent signals harmonically related to the pump and these would be obscured by harmonic generation in the varactor. The oscillators may be useful as computer storage elements since two stable choices for oscillation phase exist. The general frequency of the two-frequency varactor indicates that subharmonic generation is not possible and that frequency division, except division by 2, is not possible. With variable-capacitance diodes, oscillations have been produced at 9 kc with a 6 kc pump and at 15 Mc with a 10 Mc pump. No oscillations were obtained with the pump frequency two-fifths or less of the signal frequency.

11,547 A PARAMETRIC AMPLIFIER WITH THREE SIGNAL FREQUENCIES [in German] by K. Abel (Siemens and Halske); Entwicklungsber. S. and H., Vol. 24, pp. 104, June 1961

A parametric amplifier using three signal frequencies f_1 , f_2 , and f_3 in addition to the pump frequency f_0 in the external circuits is investigated. The energy relationships and the possible power gain in selected cases of up-conversion and direct signal amplification are discussed. It is shown that positive or negative input impedance can be produced during up-conversion and that a gain tending to infinity can be achieved during up-conversion and direct amplification of a signal whose frequency is greater than f_0 . Figures showing a sample real circuit and a sample equivalent circuit as well as an energy distribution diagram and a graph of amplification increase in two cases of up-conversion are included.

11,548 AN L-BAND TRAVELING-WAVE PARAMETRIC AMPLIFIER by S. J. Tetenbaum, F. A. Olson, and A. Savarin (Sylvania); Proc. IRE, Vol. 49, pp. 1230-1231 (L), July, 1961

A traveling-wave parametric amplifier which operates around 1.35 Gc and provides a stable gain of 10 db over approximately a 10 per cent band is described. The amplifier uses 10 diodes spaced 3.8 cm apart. Each diode has a series inductance of approximately 4 nanohenries and a static capacitance of 1 PF. The signal and idling frequencies propagate on a slab line which is periodically loaded with the diodes. Each diode is fed with a pump signal whose frequency can be arbitrarily adjusted. A band-pass filter located near the diode junction isolates the pump source from the signal and idler frequencies. Noise figure measurements with the amplifier operating in the range of 1.34 to 1.29 Gc, with 10-15 db gains, indicate a single-channel noise figure of 4 db.

11,549 A PARAMETRIC AMPLIFIER; Electronic Engrg., Vol. 33, p. 663, Oct. 1961

An experimental low-noise diode parametric amplifier and mixer, which can replace three tube stages in a conventional receiver, is described. Experiments with the device in the Marconi SR100 radar transmitter-receiver indicate an improvement in the over-all noise factor from 7 db to 2.5 db. The

device is an up-conversion amplifier using the variable-capacitance effect in semiconductor diodes to provide low-noise amplification. The pump frequency is approximately 15 times the signal frequency. Interaction between the 9200 Mc pump frequency and the 600 Mc signal transfers power from the pump to the signal. The 9200 Mc signal, with its sidebands, passes through a varactor and a band-pass filter. A crystal diode mixer extracts the IF.

Multistage Integrated Parametric Amplifier - See 11,490

Noise in Parametric Amplifiers - See 11,606

11,550 SELECTIVE HF AMPLIFICATION USING TUNNEL DIODES [in German] by K. H. Mueller (Siemens and Halske); Elektronik, Vol. 10, pp. 39-42, Feb. 1961

Formulas and local characteristic curves for tunnel diodes are derived from a frequency independent equivalent circuit. The applicability question for amplification switching is discussed in connection with bandwidth and maximum reachable amplification factor. An equivalent noise conduction value is introduced to determine the noise factor. Finally, a tunnel diode UHF tuning circuit is briefly discussed.

11,551 A TUNABLE L-BAND TUNNEL-DIODE AMPLIFIER by H. M. Wachowski (Genl. Precision Lab.); 1961 IRE Intl. Conv. Rec., pp. 64-75, 1961

A tunable L-band tunnel-diode amplifier, providing a gain of 17 db, a bandwidth of 8 Mc, and a noise figure of 6 db, is described. Since a tunnel diode has a negative dynamic resistance over a certain range of applied voltage, a one-port amplifier can be realized by terminating a uniform transmission line by a tunnel diode. The junction capacitance and parasitic series inductance of the diode must be tuned out. Being a one-port device, the amplifier is used with a circulator, or, alternatively, two amplifiers are used in conjunction with a hybrid in a balanced bridge arrangement. The outstanding advantage of such an amplifier is its extremely low power requirements.

11,552 LOW-NOISE TUNNEL DIODE REFLECTION-TYPE AMPLIFIERS by J. J. Sie (Micro State Electronics); 1961 IRE Intl. Conv. Rec., p. 128

The coupling networks used in reflection-type tunnel diode amplifiers to separate the incident and amplifier reflected waves are discussed. Two possible coupling schemes, 1) circulator, and 2) hybrid, are considered in detail with respect to gain, noise figure, stability, cascaded connections, dynamic range, and their interrelationships. The limitations of practical tunnel diodes with respect to these characteristics are discussed. Experimental data on both coupling schemes are presented and apparent noise reduction due to shot noise suppression of tunnel diodes is discussed.

Noise in Tunnel Diode Amplifiers - See 11,538

11,553 LOW-FREQUENCY INSTABILITY IN CASCADED EMITTER FOLLOWERS by K. I. Nordling (Beckman Instr.); Electronic Design, Vol. 9, pp. 36-41, Nov. 8, 1961

Equivalent circuits are developed for predicting low-frequency and high-frequency instability conditions in emitter followers. Remedial action is outlined for single and multistage amplifiers. Locus of instability curves are derived using Laplace transforms and plotted for both single and double stage emitter follower

AMPLIFIERS (Cont'd)

circuits. Test circuits are given and experimental data on locus of instability is plotted which shows close agreement with the calculated curves. There are two approaches toward stabilizing the circuit. One consists of cancelling the negative resistance by adding positive resistance in series, and the other consists of arranging for resonance to fall outside the negative resistance range. Several methods of mechanizing each approach are presented. An example of stabilization techniques in a typical design problem is given.

11,554 A SOLID STATE 125-WATT LINEAR POWER AMPLIFIER by J. A. Lostetter (Minn.-Honeywell); Semicon. Prod., Vol. 4, pp. 35-39, Oct. 1961

The design of a reliable 125 w linear class B push-pull transistor amplifier, using a common-emitter common-base compound connection which permits the use of higher than normal supply voltages, is described. The compound connection permits selection of transistors to maximize amplifier performance, and, because of the functional division of this connection, provides thermal stability. The amplifier can be used in parallel for higher power output. Experimental performance is given for 25-70°C operation.

11,555 DIRECT COUPLED AMPLIFIER FOR SMALL CURRENTS by R. A. Dandl (U.S. AEC); U. S. Pat. 3,001,144, Issued Sept. 19, 1961

A transistor amplifier capable of operating on currents below 10^{-8} a accurately, dependably, and with good stability is described. Characteristic curves for representative transistors of types 2N336 and 2N338 are given. The ratio of the incremental change in collector current to the corresponding increment of base current $\frac{\Delta I_c}{\Delta I_b} = B$ was calculated and plotted. The ratio

B was almost the same at currents of 5×10^{-6} a but diverged rapidly for lower current values. Factors limiting usefulness of transistors for low current measurements are stability or drift which masks input signal variations, residual current, or current which flows in the collector circuit with the base floating (I_{ceo}), and the current amplification (B). The ratio $\frac{I_{ceo}}{B}$ was developed as a figure of merit in that the current that can be measured with stability is equal to that ratio. Using the tested transistors input currents on the order of 10^{-12} amperes can be detected and measured accurately. The first and second stages of the amplifier employ selected transistors. The device is applicable for measurement of small currents in nuclear radiation counters, in Faraday cup type detectors for measuring very low currents of particles from particle accelerators or from plasmas from which the particles escape.

11,556 THEORETICAL CONSIDERATIONS ON BISTABLE MAGNETIC AMPLIFIERS by J. J. Suozzi (Bell Labs.); Static Relays for Electronic Circuits, Engineering Publishers, 1961, pp. 66-77

The analysis of a basic full-wave magnetic amplifier by the conventional approximate approach and by the graphical method is reviewed. Positive feedback is applied to obtain bistable action and the resulting bistable amplifier was then treated by the same two methods of analysis. The device affords galvanic isolation between input signals, has low impedance and may be controlled by small direct voltages. It may be biased to have a memory if so desired. Its ON and OFF points may be varied by changing the bias. It has a relatively slow response time

which can be shortened by increasing the actuating voltage. Also faster response times may be obtained for bistable characteristics with sharper corners which may be accomplished by the use of frequency dependent elements or by increasing the positive feedback.

Magnetic Amplifiers - See 11,518

OSCILLATORS

11,557 TUNNEL-DIODE ONE-SHOT AND TRIGGERED OSCILLATOR by T. W. Flowerday and D. D. McKibbin (Lockheed); Proc. IRE, Vol. 49, p. 1315(L), Aug. 1961

A simplified tunnel diode one-shot circuit not requiring bi-directional input pulses is described. Varying the supply voltage determines whether the circuit is bi- or monostable. Two such circuits can be capacitively coupled to form a triggered oscillator with one stable dc state and one stable ac (oscillating) state. This triggered oscillator might be used as a memory unit with nondestructive readout.

11,558 CRYSTAL-STABILIZED TUNNEL-DIODE OSCILLATORS by J. J. Nagle (RCA); Electronics, Vol. 34, pp. 40-42, Sept. 1, 1961

A crystal-controlled oscillator using a tunnel-diode as the negative resistance element is described. A pi network is used to match the diode and crystal impedances. The pi network also acts as a low-pass filter to help suppress harmonics caused by nonlinearities of the tunnel-diode. Frequency variation after two hours operation was 30 cycles with a nominal center frequency of 40 Mc. With a constant temperature, the frequency change was less than 2.5 parts in 10^8 . The temperature coefficient of frequency was 7.5 parts per million per degree C with a power output of $12 \mu\text{w}$. The output spectrum of the oscillator is free of spurious responses.

11,559 RELAXATION OSCILLATORS by E. Eberhard (RCA); U.S. Pat. 2,994,838, Issued Aug. 1, 1961

A device which utilizes the negative resistance characteristic of a three-electrode semiconductor to provide a relaxation oscillator which does not require an external feedback path between input and output is described. The common base oscillator produces pulses or a sawtooth waveform and may be triggered, synchronized or free running.

Relaxation Oscillators Using Avalanche Transistors - See 11,498

11,560 AN IMPROVED TRANSISTORIZED BLOCKING OSCILLATOR by S. Freshour (Ampex); Solid State J., Vol. 2, pp. 34-37, Oct. 1961

A theoretical analysis in which the pulse width, loading effects, recovery time and rise time of a blocking oscillator are designed to attain good pulse width predictability in conjunction with optimized recovery time is presented. The circuit is a nonsaturating collector, common-base configuration which does not depend upon transformer saturation to establish pulse width. Detailed waveform and schematic diagrams are presented. A practical circuit resulting from the analysis is shown. The circuit is capable of driving a 220 ohm load with a 4 volt, one microsecond pulse at a repetition rate of 200 kc. It is capable of rise times from 50 to 200 nsec pulse at a repetition rate of 200 kc. It is capable of rise times from 50 to 200 nsec at full load.

Switching Systems - See 11,626

11,561 A NEW BROAD-BAND ABSORPTION MODULATOR FOR RAPID SWITCHING OF MICROWAVE POWER by F. Reggia (Diamond Ord. Fuze Labs.); IRE Trans., Vol. MTT-9, pp. 343-349, July 1961

A new technique for obtaining a broadband absorption modulator for high-speed switching or amplitude modulation of microwave power is described. This ferrite modulator, an outgrowth of the longitudinal-field rectangular-waveguide phase shifter, has electrical characteristics particularly desirable in a microwave switch. These include a zero-field insertion loss of approximately 0.5 db in the ON state, and isolation of greater than 60 db in the OFF state which is nearly independent of the magnetic control field in this state, and a nearly matched input impedance for all values of applied field. These electrical characteristics are nearly constant over a 30 per cent bandwidth at X band. It is possible to design the amplitude modulator to have negligible phase shift at the desired operating frequency.

11,562 SIGNAL TRANSLATING APPARATUS by G. L. Clapton (IBM); U.S. Pat. 3,003,069, Issued Oct. 3, 1961

A high-speed bistable trigger presenting high input and low output impedances is described. To avoid the switching delay caused by minority carrier storage, the input transistor is connected in a modified grounded-base configuration. The second transistor is connected as an emitter follower. A feedback network increases the switching speed. The circuit does not require balanced transistors.

11,563 TUNNEL-DIODE BINARY COUNTER CIRCUIT by H. L. Jr (RCA); Proc. IRE, Vol. 49, pp. 1092-1093 (L), Jan. 1961

A single tunnel diode flip-flop circuit, suitable for use as a binary counter, is described. The load consists of a resistor and inductor in series. For a positive input pulse, the operating point switches, but the inductor current does not change during switching. As the inductor current decays, the operating point moves back along the characteristic curve, stopping at the second stable state. A second positive pulse causes the voltage to increase and then decay. If the circuit is underdamped, a negative overshoot develops which switches the diode. This overshoot occurs only on the second input pulse when the inductor current is small. On the first pulse, the inductor current is high and the negative overshoot is canceled by the inductance transient. A secondary winding gives pulse outputs for use as a carry in counting.

11,564 SATURABLE-TRANSFORMER SWITCHES by B. D. Simons (Siemens Edison Swan); Electronic Radio Engr., Vol. 36, pp. 82-90, Mar. 1959

The use of saturable magnetic cores in nonlinear switching is discussed. A switch which uses cores in a balanced saturable transformer is described. The on-off impedance ratio obtained by suitable design is adequate to switch magnetic recording heads for reading and writing operations. The design and construction of a saturable transformer used in a selection system in which a large number of magnetic drum heads share common read and write amplifiers are discussed. Circuits for the operation of a matrix selection system, in particular a simple transistor circuit which switches heads in a few tenths of a microsecond, are described.

11,565 MULTICHANNEL MINIMUM-AMPLITUDE COMPARATOR by R. Roy (Rensselaer Polytech. Inst.); IRE Trans., Vol. EC-10, pp. 533-534 (L), Sept. 1961

A method of selecting the data channel containing a minimum-amplitude signal, applicable to both analog and digital circuitry, is described. Minimum-amplitude detection is necessary in character recognition devices. Each data channel feeds a comparator transistor (normally off) with the emitters common to an interrogation pulse source. The channel voltages are in a direction to hold the transistors off. At a preselected time, an interrogation pulse is applied in a direction to turn the transistors on. The transistor with a minimum channel voltage applied to its base will turn on first, while the others will be held off. The circuit has been operated to one Mc with up to 100 different channels monitored. The circuit will sense a differential of 50 mv.

11,566 A SIGNAL LEVEL MONITOR FOR GO-NO-GO TESTING by W. W. Gile and D. F. Newbigging (Calif. Inst. Tech.); Electronic Design, Vol. 9, pp. 48-51, Nov. 8, 1961

A monitoring circuit which may be applied to monitor any signal that can be transduced to a varying dc level is described. The circuit acts as a high and low-level voltage comparator. If the applied signal goes above or below any preselected levels for a duration of 100µsec or longer the device will "trigger." This in turn may operate a relay, light a lamp, or initiate a command function. The circuit consists of two complementary pnp-npn monostable, highly regenerative, trigger circuits. Detailed theory of operation is given for the circuit. The complete circuit can be laid out on an etched circuit, plug-in card. Many different signals can be monitored with the use of only two power supplies. One console, designed for the Minuteman Missile capable of monitoring 60 signals, is described.

11,567 TRANSISTOR CIRCUIT by W. E. Bradley and M. Rubenoff (Philco); U.S. Pat. 2,973,437, Issued Feb. 28, 1961

A transistor circuit for signal comparison and combination is described. The circuit detects simultaneous occurrence of a predetermined characteristic in multiple inputs or the simultaneous occurrence of a plurality of separate pulse signals. A transistor has its emitter-collector path in series with that of a second transistor. Signals to be compared or combined are applied to the bases. For a signal applied to only one base, no current flows. When both bases are actuated simultaneously, a large current flows. Chains of series transistors can be combined in parallel. Reliable operation has been obtained using five surface-barrier transistors in series. By proper selection of base biasing potentials, the circuit can be used as a gate circuit, a signal translating circuit or an AND circuit.

11,568 RADAR BOXCAR CIRCUITS USING NUVISTORS, TRANSISTORS AND ZENERS by P. E. Harris (Syracuse U.); Electronics, Vol. 34, pp. 66-67, Sept. 15, 1961

A boxcar or waveform sampling circuit that provides time selection and storage, capable of achieving a 60 db signal-to-noise ratio, is described. The single stage, low-noise circuits employ a nuvistor triode with transistors and Zener diode biasing. Essential elements of a boxcar are an electronic switch, storage capacitor and isolator. The electronic switch momentarily connects the storage capacitor to the input waveform. The isolator permits reading the capacitor voltage without disturbing

SWITCHING CIRCUITS (Cont'd)

it. A low-noise, high-performance boxcar design demands that leakage resistance across the capacitor be as high as possible and that the resistance of the electronic switch, when conducting, be as low as possible. Zener diode biasing reduces the switch resistance by a factor of approximately five over R-C biasing. The circuits may be employed in military radar as moving-target detectors, as sensing elements of tracking radars and as gated (time selection) AGC.

11,569 HIGH FREQUENCY STEERING CIRCUIT by W. N. Carey, Jr. (Minn.-Honeywell); U.S. Pat. 3,011,065, Issued Nov. 28, 1961

A circuit for steering relatively large load currents by using small control currents which may be switched at very high frequencies is described. The circuit consists of a gating circuit, a single transistor and a coupling transformer; a pair of current-paths is formed by the secondary of the transformer and by a diode-biased load connected in parallel across the secondary. The pairs are then connected in series with each other and with a single load current source; a separate control circuit is provided for each pair which selects the appropriate current path in response to an input signal. Thus n control circuits will select any one of 2^n load paths.

SIGNAL CONVERTERS

11,570 FEEDBACK LINEARIZES VOLTAGE-TO-FREQUENCY CONVERTER by J. D. Long (Space-Genl.); Electronics, Vol. 34, p. 48, Sept. 1, 1961

A simple, transistorized voltage-to-frequency converter using feedback to maintain accuracy is described. The dc input voltage range, 0-3 v, produces a maximum frequency of 400 cps. The circuit utilizes a differential amplifier to compare the input and feedback voltages. The resulting signal controls a Shockley diode voltage-controlled-oscillator whose output drives a one shot multivibrator, producing the output signal and after rectification the feedback signal.

Phase Discriminator - See 11,628

11,571 THE EFFECT OF LARGE PUMP VOLTAGE ON TUNNEL DIODE DOWN CONVERTER PERFORMANCE by H. J. Prager and K. K. N. Chang (RCA Labs.); RCA Rev., Vol. 22, pp. 567-581, Oct. 1961

A theoretical analysis of a high gain, low noise factor tunnel diode mixer (down converter) is given. The tunnel diode current voltage characteristic is represented by a polynomial expansion that includes higher order terms. This expansion leads to new values of the diode conductance G_0 , a nonlinearity term GV_3 , and a noise correlation term which is not negligible for large pump voltages. Proper bias conditions may cause the correlation term to partially cancel noise. Experimental results are given which are closely predicted by the "large-pump" theory.

11,572 A MONOSTABLE TRANSISTOR CIRCUIT FOR HIGH-RATIO FREQUENCY DIVISION AND GENERATION OF SHORT PULSES by W. Steiger (Hughes Aircraft); Semicon. Prod., Vol. 4, pp. 30-35, Aug. 1961

A monostable circuit using two complementary transistors and

capable of very asymmetrical operation is described. The circuit also features timing compensated to be independent of the transistor current gains and relative insensitivity to loading and to trigger amplitude variations. Two configurations are analyzed in detail and expressions are given for the timing period, its supply voltage dependence and its temperature dependence. The final part of the timing from the instant the circuit becomes active to the regenerative switching-on, is treated in detail. One design example, a frequency divider for 10 Mc input, is described and experimental results are given.

WAVE GENERATORS

11,573 HIGH EFFICIENCY UHF POWER GENERATOR by I. Joffe (RCA Def. Electronic Prod.); U.S. Gov. Res. Rep., Vol. 36, p. 16(A), Aug. 20, 1961 AD 257 949

A high efficiency UHF generator system which illustrates novel design and circuitry is described. The feasibility model developed does not have the final form factor or the final parts envisioned for the ultimate equipment, but does use those new techniques which are presently undergoing development and which promise to be available in the early 1960's. The equipment was developed on a building block basis and incorporates the translator concept now in use at HF and UHF frequencies. Strong consideration was accorded in furthering the state of the art. The extensive use of semiconductors and the exciter-power amplifier approach are direct results of this investigation. The system described shows promise of meeting the stringent requirements of the space age.

11,574 SILICON FOUR LAYER DEVICES AS HIGH POWER PULSE GENERATORS by R. P. F. Lauder (Ferranti Ltd.); Electronics Engrg., Vol. 33, pp. 426-431, July 1961

Several circuits showing the use of four-layer pnpn semiconductor devices as narrow pulse generators, which deliver considerable quantities of power and produce accurate pulses with good leading and trailing edges, are discussed. Silicon controlled rectifiers are used to replace the switching thyatrons commonly used in pulse generator and pulse modulator circuits.

11,575 REGENERATIVE TRANSISTOR PULSE AMPLIFIERS by D. D. Ketchum (Air Force); U.S. Pat. 2,999,171, Issued Sept. 5, 1961

A circuit which produces a negative-going output pulse whose width and amplitude are essentially determined by circuit parameters is described. Emitter biasing of a point-contact transistor regenerative amplifier is developed and maintained by a zener diode. A positive pulse of sufficient magnitude to drive the transistor into saturation is applied to the emitter. The large increase in collector current causes a negative-going signal to appear at the output. The base is held negative with respect to the emitter for a predetermined interval due to the presence of an inductor in the base circuit. When the current through the inductance reverses, the emitter to base voltage is driven negative, thereby turning off the transistor. A diode connected across the coil conducts to prevent ringing. Duration of the pulse can be controlled by selected circuit parameters.

11,576 SWEEP GENERATOR by D. Randise (Sperry Rand); U.S. Pat. 2,999,174, Issued Sept. 5, 1961

A transistor sweep generator of the Miller-feedback type is discussed. The first of two cascode connected transistors is

WAVE GENERATORS (Cont'd)

employed as an electronic switch; the other is utilized as a signal amplifying device. The second transistor remains off except during the sweep-producing interval; this limits the quiescent dissipation of power. The output sweep voltage is substantially unaffected by the amplitude of the input gating signal. The device has good linearity and reduced fly-back time.

11,577 TRANSISTOR OSCILLATOR by C. J. Norton (Lear); U.S. Pat. 2,994,839, Issued Aug. 1, 1961

An improved oscillator using two junction transistors and a saturable core transformer is described. The emitter-collector paths are connected in series and by means of the saturable core transformer the transistors are rendered alternately conducting with a resultant square wave output, the frequency being determined by the saturation characteristic of the transformer.

11,578 A FOURIER TRANSFORM GENERATOR. II. by G. F. Newell and W. K. E. Geddes (BBC); Electronic Engrg., Vol. 33, pp. 646-649, Oct. 1961

Synthesis of Fourier transforms by combining harmonically related sine waves is described. The harmonics are obtained by dividing down from a higher frequency. The output of a master oscillator, operating at 120 times the lowest required frequency, is converted to pulses by a blocking oscillator and division is accomplished by bistable circuits. Sinewaves are obtained by filtering. Ten of the required harmonics are selected by division, two by taking the third harmonic of the divider outputs, and the remaining eight by intermodulation of waveforms from the divider chain. Long-term temperature stability of one part in 10^4 is obtained by using frequency-determining components in the oscillator and filters which have the same temperature coefficients. An LC network, which provides 90° phase shift, is used as a SINE/COSINE switch. The filter outputs are combined and applied to an output amplifier to obtain the desired transform.

PULSE CIRCUITS

Pulse Shaper Circuit - See 11,581

11,579 IMPULSE TIMING CHAINS by H.-J. Harloff (Siemens and Halske); U.S. Pat. 3,001,087, Issued Sept. 19, 1961

An impulse timing chain circuit employing diode amplifiers is discussed. The diode impulse amplifier is based upon the phenomenon of storage effect and consists of one diode with storage effect, one diode without storage effect and two resistors. A control impulse delivered to the input of the first amplifier is transmitted from stage to stage of the timing chain in synchronism with two feed impulses delivered to the diode amplifiers. Thus, the amplifier produces an amplification and a shifting in time of control pulses. The amplification energy is delivered by another set of feed impulses.

11,580 PULSE VOLTAGE COMPARATOR MEASURES HEIGHT OF POSITIVE OR NEGATIVE PULSES by O. B. Laug (Natl. Bur. Stand.); Electronics, Vol. 34, pp. 70-71, Sept. 8, 1961

A pulse voltage comparator capable of measuring the height of either positive or negative pulses is described. The comparator

consists of two series-triggered transistor blocking oscillators whose outputs are coupled to a monostable switching circuit that drives a relay. The circuit responds accurately to pulse duty cycles as low as 10^{-7} and pulse widths as narrow as 50 nsec; threshold voltage is adjustable from 0.5 v to 1 v and is within ± 0.5 per cent of nominal from 0° to 50°C for positive pulses. Detailed circuit theory is given. The device may be used in counting fast transients that occur at infrequent intervals and exceed the threshold level.

11,581 TRANSISTOR PRECISION PULSE SHAPER WITH SHORT RECOVERY TIME by I. De Lotto (Centro Studi Nucleari, Ispra (VA)); Alta Frequenza, Vol. 30, pp. 219-223, Mar. 1961

A pulse shaper with RC timing network is discussed. This type of timing network and the influence of transistor characteristics on the performance of this circuit are analyzed. Some circuit modifications are suggested for obtaining (1) a pulse width precision better than 2 per cent without the need for individual adjustments and (2) a pulse-width stability better than 1 per cent over a 20°C range of temperature. The circuit is so designed that the use of transistors with low base-emitter inverse voltage like the most part of the fastest types is allowed.

11,582 ZERO SUPPRESSED PULSE STRETCHER by C. E. Pallas (U.S. Navy); U.S. Pat. 2,987,633, Issued June 6, 1961

A transistorized pulse stretcher which suppresses the zero-input pulse signal from a computer magnetic core while substantially stretching the one-input pulse signal is described. An integrating circuit is employed in the input which distinguishes between the one and zero input signals, reducing the voltage amplitude of the zero signal to a tolerable level. In a typical circuit, a pulse from a magnetic core logical switching circuit was stretched from a pulse of one microsecond duration to a pulse of sixteen microsecond duration.

OTHER SOLID STATE DEVICE CIRCUITS

11,583 ACTIVE LOW-PASS RC FILTERS by D. P. Franklin (EMI); Electronic Tech., Vol. 38, No. 8, pp. 278-282, Aug. 1961

Asymptotic cutoff frequency responses from cascaded sections are discussed. By arranging the response of each section of a cascade to provide the contribution of a different pair of conjugate poles in a desired network function, the over-all response may be synthesized using simple RC ladders and buffer amplification. Details of optimum component values and suitable circuits for low-pass filters are shown. The application of the process to high-pass sections is developed in the appendix.

11,584 WAVE-CLIPPING CIRCUIT by H. C. Ruck (Bendix); U.S. Pat. 2,999,173, Issued Sept. 5, 1961

A shunt type diode-clipping circuit capable of compensating for the effect of diode forward resistance is discussed. The potential drop across the diode resulting from its forward resistance is effectively neutralized with an approximately equal potential. This is accomplished by tapping off a fraction of the input signal and applying this voltage to the output terminal. The output potential is equal to the difference between the voltage drop across the diode and the voltage tapped from

the input. The circuit yields flatter output waves even with diodes of fairly high forward resistance and has relatively low impedance. A modification of the basic circuit which clips both positive and negative half waves is given.

APPLICATIONS OF SOLID STATE DEVICES

SCIENTIFIC AND MEDICAL

11,585 MINIATURE SUBCUTANEOUS FREQUENCY MODULATED TRANSMITTER FOR BRAIN POTENTIALS by C. J. Sperry, Jr., C. P. Gadsden, C. Rodriguez, L. M. N. Bach (Tulane U.); Science, Vol. 134, pp. 1423-1424, Nov. 3, 1961

A transistorized device for broadcasting electrical signals from the brain of an animal is described. The device is encapsulated with a polyethylene resin and implanted under the animal's skin. A circuit diagram is given for the transmitter which employs two transistor stages. The first stage is an emitter-follower employed to present a high input impedance of about 250 k Ω . It is directly coupled to the second stage which functions as an amplifier-modulator-oscillator. A comparison of two electrocorticogram tracings, one recorded directly using wire leads and the other recorded by broadcasting the signal to an FM receiver before recording is shown. The signals are broadcast without distortion. Application of the device permits observation and recording of electrocortical response without the necessity of impeding normal behavior.

11,586 ELECTRONICS TO TEST LEG-BRACE FORCES by E. Peizer (NYU Res. Div.); Electronic Design, Vol. 9, pp. 12-14, Nov. 8, 1961

A research program to test leg-brace forces is described. A special leg brace fitted with an array of strain gauges has been developed by NYU researchers. The gauges are mounted with varying orientations on the slide-bars of the brace and arranged in Wheatstone-bridge circuits. The forces involved in walking can be analyzed from ink-recorded records. Another tool known as the force plate is described. The plate upon which a test subject steps is supported by four symmetrically placed columns, each supplied with 12 strain gauges. A tilt table is also described which is employed to study optimum brace conditions for good balance. The objective of the studies is the analysis and eventual improvement of brace construction.

11,587 PHYSIOLOGICAL IMPLICATION OF LASER BEAMS by L. R. Solon, R. Aronson, and G. Gould (TRG Inc.); Science, Vol. 134, pp. 1506-1508, Nov. 10, 1961

Application of the high radiation flux densities of optical masers toward biomedical practice is discussed. Two important properties of laser beams from the point of view of physiological interest are the extremely collimated character of the light and its high degree of monochromaticity. Equations are derived for retinal spot size and light intensity under various conditions. The application of the laser in experiments of the retinal burn type is given and the employment of the laser as a new energy source to experiment on its effects on ocular and other tissues

with a view toward biomedical application is suggested.

11,588 OCULAR LESIONS PRODUCED BY AN OPTICAL MASER (Laser) by M. M. Zaret, G. M. Breinin, H. Schmidt, H. Ripps, and I. M. Siegel (NYU School of Medicine); Science, Vol. 134, pp. 1525-1526, Nov. 10, 1961

Ocular lesions experimentally produced in rabbit by a pulsed optical maser (laser) are reported. Energy focused upon the surface of the retina by the refracting media is readily absorbed by the pigmented layers of the retina and neighboring choroid. Chorioretinal burns from viewing a solar eclipse or atomic fireball are typical of the lesions that may result. From a consideration of the emission characteristics of a pulsed ruby maser and the transmission properties of the eye, estimates of the energy density at the retina indicate that the burn threshold may be greatly exceeded by exposing the eye to a single 0.5 msec burst. Details of the rabbit exposure experiment are given. As amplified light systems are developed and adapted to fulfill military, industrial, and medical objectives, it is essential that attending personnel be fully cognizant of this potential hazard.

AERONAUTICAL AND SPACE

11,589 AN EXPERIMENTAL TRANSISTOR DME AIRBORNE SET by R. D. Ryan and F. G. Tonking (CSIRO) and F. R. Hall (Amalgamated Wireless); Proc. IRE, Austral., Vol. 22, pp. 552-563, Sept. 1961

An improved airborne set for the Australian 200 Mc DME system using all solid state devices (except for two valves in the transmitter) is described. Considerable reductions in size, weight, and power consumption have been achieved, together with improved performance and reliability. A major improvement has resulted from the use of the Tacan coarse-fine system of range measurement. A high accuracy (± 1 per cent) time delay circuit and a new method of automatic tracking suitable for transistors are basic elements in the unit. The 224 Mc receiver includes a crystal controlled local oscillator and a gated AGC circuit. p-n-p-n devices replace thyatrons as high power switches in the modulator.

11,590 A FORTY-EIGHT CHANNEL PULSE SELECTOR FOR THE AUSTRALIAN DME SYSTEM by P. W. Headford (Amalgamated Wireless); Proc. IRE, Austral., Vol. 22, pp. 564-569, Sept. 1961

A new transistorized pulse selector for the Australian Distance Measuring Equipment System is described. The pulse selector decodes the 48 pulse-duration/pulse-separation codes and generates a response to the selected code. The techniques which provide precise timing are discussed.

11,591 A TRANSISTORIZED AIRBORNE RECEIVER FOR THE AUSTRALIAN DME by J. Ward (Amalgamated Wireless); Proc. IRE, Austral., Vol. 22, pp. 570-576, Sept. 1961

A 224-Mc airborne receiver for the Australian Distance Measuring Equipment System is briefly described and a detailed description of the novel 30 Mc IF amplifier is given. This consists of a multi-section bandpass filter followed by a six-range broadband amplifier. The advantages of this approach are discussed.

11,592 DEVELOPMENT OF A COMMERCIAL TRANSISTOR-

AERONAUTICAL AND SPACE (Cont'd)

11,593 DIGILOCK TELEMETRY SYSTEM FOR THE AIR FORCE SPECIAL WEAPON CENTER'S BLUE SCOUT, JR. by F. R. Hall and B. R. Johnson (Amalgamated Wireless); Proc. IRE, Austl., Vol. 22, pp. 577-589, Sept. 1961

The development of a production prototype transistorized Distance Measuring Equipment Set is described. The design not only provides an equipment of light weight and low power consumption but a considerable improvement in precision, reliability and maintenance requirements has been achieved when compared with existing set. Some of the techniques used are described in detail.

11,593 DIGILOCK TELEMETRY SYSTEM FOR THE AIR FORCE SPECIAL WEAPON CENTER'S BLUE SCOUT, JR. by R. M. Jaffe (Space Electronics); Program Natl. Symp.-Space Electronics and Telemetry (A), Sept. 6, 1961

The Digilock telemetry system designed for the Blue Scout, Jr., a radiation-measuring rocket system, was described. The telemetry flight-unit commutates twenty 5-bit digital inputs, encodes the selected word into one of a family of binary orthogonal codes (the particular code selected depending on the value of input data), and phase modulates a transmitter with the selected code sequences. At the ground stations the signal is fed to a specially-designed phase-lock receiver, which demodulates the phrasing information on the received signal and applies the wideband information (which is binary in the absence of noise) to a tape recorder. The tape is played back at the data reduction center; the played-back signal is filtered by an integrate-and-dump circuit and then re-recorded on tape in a format suitable for computer-processing. The new tape is used as an input to the computer, which, by mechanizing a matched-filter type of decoder, yields the originally transmitted radiation-data. With this system it is possible to achieve a communication efficiency unsurpassed by any other existing system.

11,594 RUGGED ARMING-FUZING TIME FOR ATOMIC ARTILLERY MISSILE by R. S. Reed (Temp Instr.); Electronics, Vol. 34, pp. 48-51, Sept. 22, 1961

An electronic timing circuit which gives a high current pulse at the end of an adjustable period is described. An arming and fuzing programmer that employs digital techniques was developed to satisfy stringent accuracy requirements, 0.1 sec in 100 seconds, and extreme range of adjustment specified, 0 to 99.9 seconds in increments of 0.1 seconds. A clock oscillator and pulse shaper with frequency dividers forms the time base generator that provides pulses to decade counters. Appropriate timing outputs from the decades are selected and coupled through switches to the input of the first arming AND gate. Remaining AND gates are wired directly to decades to fire at predetermined intervals after the first AND gate fires. Circuit details are presented and specifications are given. The device is meant to replace present arming and fusing devices which contain less reliable mechanical subassemblies.

11,595 INSTRUMENTATION AND TELEMETRY OF TRANSIT NAVIGATIONAL SATELLITES by J. W. Hamblen and J. B. Dakes (Johns Hopkins U.); Electronics, Vol. 34, pp. 148-153, Aug. 11, 1961

Instrumentation and telemetry circuitry used in Project Transit, an all-weather global navigation system, is described. The transit navigation system is based upon the ability to extract accurate positional information from the measured doppler shift of the satellite's transmitter during a single passage within range

of a single tracking system. To investigate the effect of ionospheric refraction, each satellite has four transmitters, operating between 54 and 324 Mc, arranged in pairs. This provides a two-frequency real-time refraction correction by phase comparison, in addition to the four-frequency refraction investigation. A telemetering transmitter furnishes thermal and solar environmental data. Frequency variation of the crystal-controlled oscillator is less than 5 parts in 10^9 in a 15 min orbital pass. Time division multiplexing is used in the telemetry system. A single broadband antenna is made by projecting two sets of double spiral slots on the surface of each hemisphere so that feed points are diametrically opposed. Power is supplied from nickel-cadmium batteries which are recharged by solar cells.

11,596 CRITICAL ENGINEERING FACTORS IN THE DESIGN AND DEVELOPMENT OF SPACE SYSTEMS by J. M. Bridges (Director of Def. Res.); J. Brit. IRE, Vol. 22, pp. 275-279, Oct. 1961

Basic concepts underlying the design and development of systems for space operations are discussed. The importance of mathematical prediction of system reliability, using known failure rates is stressed. Enough samples should be tested at each level of system assembly to provide statistically valid assurance of the entire system's Mean-Time-to-Failure. Reducing system weight and standardizing components is of great economic importance. Areas in which research is needed to predict and measure reliability including techniques of self-healing for components and circuits, advanced methods employing redundancy, fail-safe techniques and self-organizing systems and development of techniques for sealing and lubrication in high vacuum are discussed.

RADIO AND TELEVISION

11,597 DESIGN OF ANTENNAVERTERS AND ANTENNAFIERS by J. R. Copeland and W. J. Robertson (Ohio State U.); Electronics, Vol. 34, pp. 68-71, Oct. 6, 1961

Antenna-receiving system combinations in which part of the receiver circuit is integrated into the antenna are described. The antennavert is an integrated antenna and heterodyne converter. A tunnel diode down converter provides a stable conversion gain of 9 db with an over-all two-channel noise figure of 7 db in the UHF range. In the antennafier, the RF amplifier and antenna are a unified structure with a traveling-wave amplifier distributed throughout the antenna structure. The device has a low noise potential since amplification occurs at point of signal reception. The noise-figure is determined by measurements of field strength sensitivity.

11,598 TRANSISTORIZED DIRECT VOLTAGE CONVERTER 6v:3kv [in German] by G. Knauer (Telefunken, Ulm.); Elektron. Rundschau, Vol. 15, p. 417, Sept. 1961

An experimental transistorized direct voltage converter with its series-produced horizontal-output transformer for TV is described. The no load-voltage is 3kv, and the internal resistance is 750 kohms. Maximum current at 1.7kv is 1.7 ma.

TELEPHONY, TELEGRAPHY, AND TELEMETRY

11,599 RECEIVERS FOR USE IN ELECTRIC SIGNALLING

TELEPHONY, TELEGRAPHY, AND TELEMETRY (Cont'd)

SYSTEMS by D. C. Tyler (GE); U.S. Pat. 2,999,170, Issued Sept. 5, 1961

A switching arrangement for receivers employed in electric signalling systems is described. Information is transmitted by the occurrence of one or other of a small plurality of discrete states of an electrical variable between which relatively rapid transitions occur. The variable may be the magnitude of a direct current or the amplitude or frequency of a carrier wave. A junction transistor switch is arranged to operate in response to received signals. The receiver includes a generator adapted to produce at least one output voltage pulse in response to application of received signal pulse. The generator pulses are appreciably shorter than the transitions between the discrete states of the electric variable in the received signal. A means is provided for applying the generator output voltage(s) to operate the switching arrangement. The receivers are applicable in telegraph systems and telecommunication systems in which dialing impulses are transmitted.

11,600 TRANSISTORIZED CARRIER TELEPHONE EQUIPMENT (3) by W. Beijinck and J. C. Lodder; Philips Telecommun. Rev., Vol. 22, pp. 162-172, July 1961

A transistorized power supply for the previously discussed 12 and 24 channel carrier telephone equipment (8TR202 and 8TR206) is described. Advantages of transistor equipment and the factors leading to the choice of the system supply voltage are given. Circuit protection may be adequately provided by 100 ohm resistors making fuses unnecessary. Converters for operation from 24, 48 or 60 v batteries with a stabilized output of $21 \text{ v} \pm 2 \text{ per cent}$ at constant load 0.2-4.5 amp are presented. Equipment for power feeding of buried repeaters is discussed.

11,601 TRANSISTOR KEYING IN THE LOCAL LOOP OF TELEGRAPHY TRANSMISSION EQUIPMENT [in German] by A. Aulmann (Siemens and Halske); Nachrichtentech. Z., Vol. 14, pp. 344-348, July 1961

The substitution of transistor switching circuits for electromechanical relays in double-current keying telegraphic devices is discussed. Several circuits are presented and compared with relays taking into consideration the special requirements of telegraphy.

11,602 HIGH SPEED SOLID STATE PCM ENCODER by T. R. Gregory (Sonex); Prog. Natl. Symp.-Space Electronics and Telemetry (A), Sept. 6, 1961

A high speed encoder developed for a miniature high environmental P.C.M. system was described. The bit rate is 400 kc at a 10 bit accuracy (0.1 per cent) plus 2 bits for synchronization and word identification respectively. Included in the input is sample and hold circuitry that allows practical maximization of the frequency response of each commutated channel. Theoretical circuit analysis of the circuitry employed, plus experimental results are also included.

11,603 LOW-SPEED TIME-MULTIPLEXING WITH MAGNETIC LATCHING RELAYS by J. F. Meyer (Calif. Inst. Tech.); IRE Trans., Vol. SET-7, pp. 34-41, June 1961

A multiplexing system designed specifically for low-speed operation and multiple-rate flexibility so as to gain advantage in other critical areas of performance is discussed. A unique syn-

thesis of the basic circuit provides for the time-multiplexing of n measurements with $n-1$ magnetic latching relays. Assuming an external two-phase clocking source, no other components, active or passive, are required in the circuit. Other advantages of the circuit are: 1) low average power consumption, 2) no additional monitoring or reset circuitry required to insure proper operation at turn-on or after momentary power failure, and 3) the virtual impossibility of switching more than a single measurement to the common output line, even in the case of component or wiring failure.

11,604 CANADIANS SIMULATE ADAPTIVE COMMUNICATIONS SYSTEM by A. Corneretto (Electronic Design); Electronic Design, Vol. 9, pp. 8-10, Nov. 8, 1961

An adaptive communication system, designed to transfer digital data at a variable rate, which has been simulated with digital modules is reported. The performance of the system correlates with predictions and indicates that an on-the-air system would be able to maintain a constant error rate despite channel fluctuations. In the Canadian system, phase-modulated sequences of binary digits are transmitted with a variable degree of redundancy to a receiver, in which the incoming sequence is compared with a local stored copy of the transmitter sequence. After accuracy of the receiver message is determined, the data rate is modified by changing, through a feedback channel, the amount of redundancy needed to maintain a desired error rate. A discussion of feedback-type adaptive communication systems including a block diagram is given. The systems fall into two classes: predecision, in which channel data is supplied to the transmitter, and post decision, in which the results of individual receiver decisions are supplied. Both types are closed-loop, two-directional systems. Open-loop systems employ filtering to achieve adaptation.

Telemetry for Blue Scout Rocket - See 11,593

Satellite Telemetry System - See 11,595

MICROWAVES AND ULTRAMICROWAVES

11,605 FERRITE COMPONENTS FOR UHF AND MICROWAVE SYSTEMS by J. C. Cacheris and N. G. Sakiotis (Motorola); Electronics, Vol. 34, pp. 37-42, Sept. 22, 1961

Recent designs of ferrite isolators, circulators, switches and phase shifters for UHF and microwave systems are described. Numerous examples are presented for each component function including physical construction diagrams, equivalent circuits and attenuation versus frequency characteristics. Losses in ferromagnetic materials depend upon both dielectric and magnetic properties. At frequencies above 100 Mc dielectric loss is constant with frequency and can usually be reduced to an acceptable level by preparation of the material. Magnetic loss has a complex dependence upon material, frequency, applied magnetic field strength and the r-f field intensity. In general two regions exist for low-loss operation at small values of applied field strength. At present the low-loss region includes all frequencies above 1,300 Mc and those below 60 Mc. Component devices are suitable for both low and high power applications.

MICROWAVES AND ULTRAMICROWAVES (Cont'd)

11,606 COMPUTING NOISE LEVELS IN MICROWAVE RECEIVER SYSTEMS by H. H. Grimm (GE); Electronics, Vol. 34, pp. 52-55, Aug. 4, 1961

An evaluation of all noise entering a microwave receiver system is presented. Particular attention is given to maser and parametric amplifiers and the requirements placed on the rest of the system by their low noise levels. The noise power level is calculated on a block by block basis and formulas are derived for the different noise sources. The set of computations given illustrates most of the aspects of the noise problems encountered in a system.

Microwave Maser Amplifier - See 11,527

11,607 SOME FACTORS AFFECTING APPLICABILITY OF OPTICAL-BAND RADIO (COHERENT LIGHT) TO COMMUNICATION by D. G. C. Luck (RCA Adv. Mil. Systems); RCA (Rev.), Vol. 22, pp. 359-409, Oct. 1961

A detailed discussion of numerous technical factors which determine the suitability of optical-band transmission, using coherent light, for future communication systems is presented. Optical-band coherent radio provides a tremendous available spectrum and an extreme directivity. Its capability is limited by fluctuation noise inherent in the generation and detection of the wanted signal itself, and there is some difficulty in eliminating unwanted modes to produce a pure signal. In most respects it is closely similar to other radio communication systems. Characteristics of equipment for working with radio signals in the optical-band are described giving particular attention to coherent optical-power generators, power supply conversion devices, modulators, and detectors. Some system-performance comparisons with older bands are made which bring out the great advantage obtainable from the ease of attaining high directivity in the optical-band in spite of the penalty for quantum noise limitations.

RECORDING AND REPRODUCTION

11,608 MAGNETIC RECORDING - THEORY OF TAPE MAGNETIZATION by L. G. Sebestyen and J. Takacs; Electronic Tech., Vol. 38, pp. 274-278, Aug. 1961

A novel explanation for the magnetization of magnetic tape and the role of ac bias is discussed. An attempt is made to present the problem in a form suitable for mathematical analysis. The salient point of the theory is that it is the bias waveform which is written on the tape while the signal appears as "modulation" of this carrier. The replay channel, especially the replay head, acts as a low-pass filter and extracts the information from the modulated carrier. In spite of gross simplifications, several unexplained phenomena can be accounted for on the basis of this analysis. A simple experiment proves the salient points of the theory.

11,609 PHASE EQUALIZATION IS IMPORTANT by F. Jorgensen (Minn. Min. and Mfg.); Electronic Ind., Vol. 20, pp. 98-101, Oct. 1961

The importance of phase equalization in magnetic instrumentation on recording to insure accurate waveform reproduction and data correlation is described. A magnetic record-playback analog is shown schematically. The effect of thickness, gap,

spacing, and head losses on the amplitude and phase characteristic responses are described. The magnetic record-playback process violates the almost universal rule for electrical networks: "If the frequency response is flat within a certain frequency range, there is no phase shift within the same range." The concept of envelope delay is defined as the slope of the phase characteristic. The envelope delay must be a constant for a complex waveform to be correctly reproduced. Constant phase equalizers using delay line techniques are employed to eliminate phase distortion.

11,610 A STUDY OF THE PLAYBACK PROCESS OF A MAGNETIC RING HEAD by G. J. Fan (IBM); IBM J. Res. and Dev., Vol. 5, pp. 321-325, Oct. 1961

Using the theorem of reciprocity, the playback process of a magnetic ring head with finite permeability of head and tape is considered. To obtain an accurate result for the playback process, the field around a magnetic gap is studied by a Fourier method. The shift of the gap null for infinite permeability of the head as calculated by Westmijze is confirmed and the new shift is found when the tape permeability is greater than one. A simplified gap-loss function for the case of finite parameters for tape and head is given.

COMPUTERS

Computer Analysis of Feedback in Amplifiers - See 11,540

11,611 TUNNEL DIODES INCREASE DIGITAL-CIRCUIT SWITCHING SPEEDS by W. V. Harrison and R. S. Foot (Texas Instr.); Electronics, Vol. 34, pp. 154-156, Aug. 11, 1961

The combination of GaAs tunnel diodes and transistor circuitry to obtain high-speed digital operation is described. Advantages are: input-output isolation, direct pulse inversion, unidirectional information flow, easier coupling and widening of the peak current tolerance. Emitter followers accomplish pulse steering and impedance transformation, while nsec pulse transformers and transistor amplifiers provide inversion and amplification. The fan-out problem normally associated with direct tunnel diode logic is removed by use of emitter followers. Clock pulse generators capable of speeds beyond 100 Mc, dual variable delay square pulse generators capable of 50 Mc operation, shift registers with shift speeds approaching 50 Mc, programmable pulse generators capable of operating with clock rates to 50 Mc and cascaded binary stages capable of countdown from inputs of 140 Mc are described.

11,612 A BIBLIOGRAPHICAL SKETCH OF ALL-MAGNETIC LOGIC SCHEMES by D. R. Bennion, H. D. Crane, and D. C. Engelbart (Stanford Res. Inst.); IRE Trans., Vol. EC-10, pp. 203-206, June 1961

A history of all-magnetic logic schemes and a bibliography of pertinent literature, covering both resistance schemes (dependent upon coupling-loop resistance) and nonresistance schemes (possessing at least first-order independence of coupling-loop resistance), are presented. Included are: 1) schemes using electric-circuit transfer linkage with simple cores, multi-path cores, and thin-film elements; and 2) schemes using continuous magnetic structures in which transfer linkage is purely magnetic.

11,613 PARITY CHECK SWITCHING CIRCUIT by J. J. Moyer (IBM); U.S. Pat. 3,011,073, Issued Nov. 28, 1961

A relatively simple switching circuit designed to resolve the

COMPUTERS (Cont'd)

parity of two register stages simultaneously is described. The circuit makes use of four OR gates and four AND sections requiring a total of eight transistors and twenty-four diodes to check the parity of six register stages. Each OR gate is responsive to a pair of dc signals representing a selected combination of digits in the two register stages; the proper AND circuit is selected by two dc signal inputs derived from the OR gates, and one pulse signal input representing the parity of the lower ordered register stages. In this way the pulse is caused to appear at the proper AND section in the logical combination serving the next higher ordered pair of register stages as an indication of the parity of all the preceding stages.

11,614 RESEARCH ON MULTI-APERTURE MAGNETIC LOGIC DEVICES by D. R. Bennion (Stanford Res. Inst.); U.S. Gov. Res. Rep., Vol. 35, p. 767(A), June 16, 1961 PB 148231

Methods for describing and measuring the properties (static and dynamic) of magnetic materials, devices, and circuits are presented. A new approach to the development of practical switching models is introduced for use in the analysis of flux transfer in all-magnetic circuits. Various means are discussed for realizing an OR-NOR logic module with one or more multi-aperture devices, alone or in conjunction with toroids. One such module makes use of a pair of PLUS-MINUS devices (components that can be wired for either direct or complementary transfer of information). A particular design for a device of this type is singled out for more detailed study. Ultrasonically fabricated units were tested individually and in operating circuits. Drive current ranges of 15 to 45 per cent were obtained for the various modes of operation. The device design is diagnosed and possibilities for substantial improvements are indicated. It is concluded that this particular approach to all-magnetic logic is a sound one.

11,615 PROGRAMMED SUPERCONDUCTOR RING COMMUTATOR by D. J. Dumin (IBM); U.S. Pat. 3,002,111, Issued Sept. 26, 1961

Programmable superconductor circuitry, operable as a ring or commutator, is described. Improved superconductor circuits of the ring and/or commutator types are presented. A plurality of superconductor bistable circuits, each of which forms one stage and is capable of assuming an ON and OFF state, constitute the commutator ring. Each stage successively turns on the next stage and is coupled in such a way as to turn off the second stage preceding it in the ring. The duration of output pulses produced are precisely defined. The coupling between the stages is in the form of a program circuit which is controllable to selectively render each of the stages responsive to change states under the control of any one of a number of other stages in the ring.

11,616 REVERSIBLE DECIMAL COUNTERS by J. L. Goldberg (CSIRO, Austl.); Electronic Tech., Vol. 38, pp. 234-245, July 1961

Counters which reverse their direction of counting in response to external control signals are described. These devices are required in the application of optical interferometry to the precise measurement of length. Two different scales of notation, namely the binary and the bi-quinary, are shown to be of particular interest in the realization of a reversible decimal scale. In the binary system, the basis of the device is a scale-of-sixteen counter formed from four cascaded binary units.

With interconnection of the units through two sets of transfer gates, the direction of counting may be reversed by enabling one set and disabling the other. Two particular numbers in coded binary form are converted to single digits and, by a process of resetting, these effect the necessary corrections to produce a decimal scale in both directions of counting. These corrections are intended to preserve the same constant place weight in both cases and thus make a single decoder necessary to interpret the count at any instant. A reversible bi-quinary, or 2-5, scale may be realized by interposing transfer gates between a binary stage and a five-element ring counter. No scale correction is required in this case. Both types of counter are constructed from three basic circuit elements using junction transistors and diodes. The design and use of these elements is considered in detail.

Tunnel Diode Binary Counter - See 11,563

11,617 A MODULO TWO ADDER FOR THREE INPUTS USING A SINGLE TUNNEL DIODE by K. S. Menger (Harvard Comp. Lab.); IRE Trans., Vol. EC-10, pp. 530-531 (L), Sept. 1961

The design of a single tunnel diode modulo two adder, using the negative resistance characteristic of the diode, is described. Piece-wise linear approximation is used to develop the design. The measured outputs for the 2^3 possible switch settings are tabulated. By eliminating one of the three inputs, a two-input modulo two adder (EXCLUSIVE OR logic) is obtained. Biasing one of the two inputs provides an inverter. The design principle may be extended to symmetric logic with more than three inputs by placing tunnel diodes in series. The composite characteristic of n diodes in series has n distinct negative resistance regions and accommodates $2n + 1$ inputs.

Parametric Storage Units - See 11,546

Phase Equalization in Magnetic Recording - See 11,609

Theory of Tape Magnetization - See 11,609

11,618 THE ADDRESS SYSTEM AND INCREMENT STORE FOR A DIGITAL DIFFERENTIAL ANALYSER by P. L. Owen, M. F. Partridge, and T. R. H. Sizer (Roy. Aircraft Estab.); Electronic Engrg., Vol. 33, pp. 656-663, Oct. 1961

The address system and overflow increment store of a digital differential analyzer is described. Patch panel interconnection of integrators, corresponding to the flow diagram representing the problem solution, is used. The incorporation of AND gates in the patch plugs saves space and components within the computer. The patch panel system is similar to programming an analog computer and permits program checking by visual observation. The equipment has operated satisfactorily for more than 1000 hours.

Shift Registers Using Tunnel Diodes and Transistors - See 11,611

Clock Pulse Generators Using Transistors and Tunnel Diodes - See 11,611

Digital Analog Converter for Motor Speed Regulation - See 11,623

11,619 THE TRANSISTOR IN VOLTAGE AND CURRENT STABILIZERS [in German] by H. J. Bederke and H. Mueller; AEG Prog., No. 1, pp. 146-151, 1961

The basic circuit and method of operation of electronically controlled sources of direct voltage are explained. Supplementary disturbance injection, current limiting and short-circuit protective circuits improve the control characteristics and protect the transistors and following equipment. For applications where the requirements as to constancy and ripple are not so stringent but high outputs are required equipment has been developed in which the transistors work as switches. The special advantages of transistor stabilizers for use in industrial plants are considered.

Telephone Carrier Power Converters - See 11,600

11,620 A TRANSISTORIZED L.T. REGULATOR by J. H. Deichen (Marconi Instr.); Electronic Engrg., Vol. 31, pp. 688-689, Nov. 1959

Methods of providing a stabilized dc supply for vacuum tube heaters are examined and their limitations are discussed. A simple regulating circuit using a transistor and two Zener diodes is then given and its design and performance are described. The circuit shows a thirty-to-one improvement over the conventional cathode-follower vacuum tube regulator.

11,621 A DESIGN PROCEDURE FOR SILICON REGULATOR DIODE DC VOLTAGE REGULATORS by R. G. McKenna (Texas Instr.); Solid State J., Vol. 2, pp. 38-42, Oct. 1961

A method of designing dc voltage regulators employing Zener diodes is given. For specific application, the load voltage and current supply voltage may be estimated. The design procedure consists in the selection of the proper diode and the determination of an input voltage and series resistance that will provide regulation over the required load current and input voltage changes without overloading the diode. Equations for optimum design of Zener diode voltage regulators are derived and applications of the results are illustrated in two example configurations.

11,622 HALF-BRIDGE INVERTER PROVIDES ECONOMICAL THREE-PHASE POWER by A. G. Lloyd (Daven); Electronics, Vol. 34, pp. 62-65, Sept. 15, 1961

An economical inverter circuit suitable for both two-phase and three-phase applications is described. The basic circuit for the half-bridge inverter is discussed. Only two transistors are used with two capacitors and a specially wound transformer. Voltage output is switched in a square wave mode from minus one-half to plus one-half of the total dc input voltage. Switching is caused by magnetic saturation of the transformer core. The circuit may easily be de-spiked by connecting a diode across each transistor. In a practical inverter, means are prescribed to insure symmetry between the alternating output pulses. Sections may be connected in series to yield a high dc input voltage inverter or in parallel for two-phase and three-phase operation. Efficiencies of 85 per cent or better are possible.

Power Converters - See 11,598

11,623 SPEED REGULATION BY DIGITAL METHODS by W. C. Schmidt and R. R. Potts (Reliance Electric); Electrical Engrg., Vol. 80, pp. 842-845, Nov. 1961

A method of applying digital techniques to speed regulating systems is described. The heart of the system is the digital error register or reversible pulse counter. The counter has two inputs. Pulses applied to the positive input cause the register to count forward; pulses applied to the negative input cause it to count in reverse. In the system a crystal controlled oscillator supplies one input to the error register. The other input is supplied from a pulse tach transducer in which one feedback pulse is generated for each increment of rotation. The net accumulated count difference is observed in the error register. This information is converted by a digital analog converter into a voltage proportional to the error count both in magnitude and polarity. This voltage is applied directly to an electronic drive which controls the motor speed. More involved speed regulating systems are also described. It is possible to regulate the controlled variable to accuracies not attainable by other methods.

11,624 DIGITAL CONTROL OF MACHINE TOOLS by J. Tlustý; Czech. Heavy Ind., pp. 11-21, Sept. 1961

The specification and design of digital control of machine tools is described. Digital control is the most suitable form of automation of machine tools for small-lot production. The program of the cycle of tool motion relative to the workpiece is determined by a system of digits expressed in a code in the form of a punched tape or punched cards. Requirements imposed on digital control systems for various kinds of machine tools are: number of controlled coordinates, shape of the cycle, remote visual indication of position, zero offset of coordinates, automatic modification of instructions with respect to the actual diameter, and accuracy, range and speed of the system. General design considerations for control systems are presented for two basic groups: systems of point-to-point control, and continuous-path control systems. Applications of control systems to lathes, milling machines, drilling and boring machines are given.

11,625 DESIGN OF POSITION SERVOMECHANISM OF A MACHINE TOOL WITH DIGITAL CONTROL FOR ATTAINMENT OF MAXIMUM TRACING VELOCITY by J. Zelený and M. Halouská; Czech. Heavy Ind., pp. 22-27, Sept. 1961

Continual-path systems for a machine tool with digital control are described. Two requirements which must be met for such systems are: (1) The servomechanism must possess stability in all working conditions and quick damping in the transition regimes, (2) the servomechanism must present a quick transient response and minimum dynamic errors. Basic types of differential members for continuous path control systems analyzed in detail are: the pulse-servomechanism with a numerically operating differential member; the phase servomechanism; the phase-pulse servomechanism; the analog system; the system with a low-power step motor and with a copying servomechanism; the system with position-servomechanisms in series connection. Block diagrams and characteristics of the feedback systems are presented.

CONTROL APPLICATIONS (Cont'd)

11,626 DESIGN OF SIGNAL AND CONTROL STATIC RELAYS by R. Langfelder (Walter Kidde); Static Relays for Electronic Circuits, Engineering Publishers, 1961, pp. 41-56

The replacement of, and improvement on, mechanical relays by transistorized static relays is discussed. Contact rating ranges were given for four semiconductor types. Snap action can be provided by use of regenerative elements such as the controlled rectifier, unijunction, four layer diode, and tunnel diode or of non-regenerative elements connected in regenerative circuits such as the blocking oscillator, Schmitt trigger, and the bistable multivibrator. Detailed design considerations were discussed including circuit diagrams for transistor static relays (including modifications of the basic configuration to provide different contact arrangements), controlled rectifier static relays, and signal relays (symmetrical transistor, photoconductor, and biased-diode).

INSTRUMENTATION

Amplifier for Low Current (10^{-8} amperes) Measurements - See 11,555

11,627 SENSITIVITY ERROR IN FREQUENCY MEASUREMENTS WITH THE WEIN BRIDGE by H. H. Wolff (Republic Aviation); Rev. Sci. Instr., Vol. 32, pp. 902-905, Aug. 1961

The relative accuracy of a Wein Bridge in frequency measurements is considered. Specifically the error which results from the uncertainty in the null adjustment that is due to the limitation in the null instrument sensitivity is discussed. Formulas for the relative error in frequency measurement and for optimum bridge parameters are derived. The influence of deviations from the optimum parameters is shown and discussed. For bridges covering a wide frequency range, certain free parameters should be made adjustable to maintain good sensitivity.

11,628 MEASURING PHASE WITH TRANSISTOR FLIP-FLOPS by J. R. Woodbury (Stanford Res. Inst.); Electronics, Vol. 34, p. 56, Sept. 22, 1961

A transistor flip-flop circuit which measures the phase difference between two sinusoidal inputs is described. The phase meter comprises two limiters, each driven by one of the input signals. Each limiter drives one side of a high-speed multivibrator through differentiating and clipping circuits. The output of the flip-flop is a square wave which turns on when one input signal goes negative and off when the other input signal goes negative. The dc value of the output is therefore proportional to the phase difference of the two inputs. A schematic and circuit details are presented. The circuit gives good results with 3 kc sinusoidal inputs possessing an amplitude of $4V_{rms}$ or greater.

11,629 DOUBLE-PROBE AND TRIPLE-PROBE SEMICONDUCTOR DEVICES FOR THE SIMULTANEOUS MEASUREMENT OF TWO OR THREE COMPONENTS OF MAGNETIC INDUCTION [in Czech] by I. Hlasnik and K. Merinsky (Lab. Elect. Engrg., Slovak Acad. Sci., Bratislava); Elektrotech. Cas., Vol. 12, No. 7, pp. 447-453, 1961

Two new semiconductor devices which enable the simultaneous measurement of two or three components of the magnetic induction vector are described. The elements work on the Hall effect

principle, but unlike the normal Hall generator they allow measurement of the magnitude and direction of the magnetic induction vector without turning in the space. Experimental results confirm the acceptability of these devices for the measurement of the magnetic induction vector.

11,630 INFRARED CIRCUITS IN TIROS SATELLITES. I. by F. Schwarz (Barnes Engrg.); Electronics, Vol. 34, pp. 43-45, Sept. 22, 1961

A 5-channel radiometer that measures parameters dealing with the earth's heat is described. The device was carried into orbit by NASA's Tiros II and functioned continuously over five months before it was disabled. The electronic circuits were designed for low power consumption, compactness, low weight, and for ability to withstand the temperature environment of -10° to 50° C and the shock and vibration expected during launch. The radiometer contains optical choppers to modulate the signal output of a thermistor detector. The thermistor output is fed into a narrow-band amplifier whose output is rectified by a diode bridge to produce a push-pull dc output to a voltage controlled oscillator. The oscillator output is recorded on magnetic tape. Detailed circuitry and design data are presented.

Radiation Position Indicator Employing Lateral Photovoltaic Effect - See 11,515

Decimal Counters for Interferometry - See 11,616

11,631 MEASUREMENT OF RAPID TEMPERATURE CHANGES BY THERMOCOUPLES by J. A. Sirs (U. London); J. Sci. Instr. Vol. 38, pp. 489-490, 1961

A simple phase advancing network to increase the rise time of small copper-constantan and copper-Eureka metal thermocouples is described. The time constant for one small couple was reduced from 15 msec to about 1 msec, at the expense of some output amplitude.

11,632 DYNAMIC FLUID SWITCH SENSES ACCELERATION by F. W. Kear; Electronics, Vol. 34, pp. 64-67, Sept. 22, 1961

A transistorized accelerometer which employs a dynamic fluid switch to sense acceleration is described. Fluid is contained in a cylindrical section that is rotated so that centrifugal force tends to move the fluid upward and toward the outer wall. The acceleration force parallel to the axis of rotation tends to move the fluid downward. When the centrifugal force just overcomes the force of acceleration the fluid contacts an upper switch probe. The required centrifugal force indicates acceleration and can be measured in terms of accelerometer motor speed. The sensing probe causes power to be switched on and off to the motor to maintain the relationship between motor speed and acceleration. Details and associated transistor circuitry required for operation of the accelerometer are given. The device is useful in measuring acceleration in ballistics missiles and jet-powered aircraft.

11,633 CERIUM-ACTIVATED SCINTILLATING GLASSES by R. Ginther (U.S. Naval Res. Lab.); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 521-529

Cerium-activated glasses with promising scintillating properties are discussed. A wide variety of glasses employing nearly all of the activators known to produce luminescence in crystal

phosphors have been synthesized, but scintillation pulses have been obtained only with cerium-activated samples. The first group of scintillating glasses developed were borates and the most efficient of these are a sodium aluminum borate and a magnesium aluminum borate. A somewhat more efficient glass is obtained by partial substitution of silica for boric oxide in the alkali-bearing glass to produce a sodium aluminum borosilicate. The most efficient glass prepared is a lithium magnesium aluminum silicate having a pulse height 14 per cent of a NaLi (Te) crystal. The effect of compositional variation has been studied extensively. The emission of all the above glasses lies in the near ultraviolet and blue region of the spectrum. The boron and lithium containing glasses have been found to detect thermal neutrons, and the sodium aluminum borate glass appears to be a very promising detector for time-of-flight experiments.

11,634 SOLID SCINTILLATORS, SOME MANUFACTURING AND RESEARCH ASPECTS by G. A. Giger (La Radiotech.); Electronic Applic., Vol. 21, No. 3, pp. 89-105, 1960-61

The properties and mechanisms of scintillation phosphors are described. A definition and brief review of a phosphor is given and the use of a scintillation phosphor in conjunction with a photomultiplier is described. The phenomenon of phosphorescence is explained and solid scintillators are described and broken down into two classes: organic and inorganic. The properties and preparation of the most widely used compounds are covered and scintillator applications are described. Possibilities for scintillator application now under investigation are detailed.

11,635 A SOLID-STATE BRAGG-GRAY CAVITY CHAMBER by U. H. Ritz and F. H. Attix (U.S. Naval Res. Lab.); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 481-490

A solid state analog of a Bragg-Gray cavity ionization chamber is described. Thin layers of materials sensitive to radiation are placed between walls of C, Al, Cu, Sn, or Pb. Two types of sensing agents have been employed: a thin layer of anthracene whose ultraviolet-induced luminescence degrades upon irradiation, and 6 μ thick polyethylene terephthalate (Mylar) films whose optical density at 3250 Å increases upon irradiation. Results in a Co^{60} γ -ray field with anthracene disagree sharply with theory, while the Mylar film yields excellent agreement (± 5 per cent) with theory. A preliminary attempt to discriminate between fast neutron and gamma ray dose in a nuclear reactor has been unsuccessful.

11,636 NEW HIGH-SENSITIVITY SILVER-ACTIVATED PHOSPHATE GLASS FOR THERMAL NEUTRONS by R. Yokota and E. Nakai (Tokyo-Sibaura Elect. and Japan Atomic Energy Res. Inst.); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 497-501

A new Ag-activated phosphate glass which is highly sensitive to thermal neutrons is discussed. The glass contains a large amount of Li and a small amount of B. It has a greater sensitivity to thermal neutrons than Schulman's glass. By exposing two pieces of glass, one covered by a brass plate and the other by a Cd plate, thermal neutrons and γ -rays can be measured separately.

11,637 SILVER METAPHOSPHATE GLASS FOR GAMMA-RAY

MEASUREMENTS IN CO-EXISTENT NEUTRON AND GAMMA-RADIATION FIELDS by J. A. Auxier, C. H. Bernard, and W. T. Thornton (Oak Ridge Natl. Lab.); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 503-510

The exposure of small glass rods composed of the metaphosphates of Al, Ba, K, and Ag to both neutrons and gamma radiation to determine their suitability as gamma dosimeters in gamma radiation fields coexistent with neutrons is discussed. For energies less than 300 keV, the response per unit exposure dose is a function of photon energy with a peak at approximately 55 keV. Filters in the form of cylindrical capsules eliminate the major portion of this increase response per unit of exposure dose in the photoelectric region. The fast neutron response was determined in the energy range of 0.5 to 1.5 MeV; the upper limit of response in this range of energies was 0.7 per cent compared to Co^{60} gamma radiation in units of tissue rad. A thermal neutron response equivalent to an exposure dose of 1 r of Co^{60} gamma rays was induced by $(2.96 \pm 0.38) \times 10^9 n_T/\text{cm}^2$. Preliminary measurements with similar rods in which Ba and K had been replaced by Mg and Li, respectively, indicate a lower peak gamma ray response per unit of exposure dose in the photoelectric region and an increased sensitivity to thermal neutrons; 1 r equivalent response was produced by $(3.7 \pm 0.4) \times 10^8 n_T/\text{cm}^2$.

11,638 A NEW THERMOLUMINESCENT DOSIMETER by J. H. Schulman, F. H. Attix, E. J. West, and R. J. Ginther (U.S. Naval Res. Lab.); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 531-540

A simple dosimeter design in which a thermoluminescent phosphor is mounted on an electrically heatable support in an evacuated or gas-filled envelope is described. With $\text{CaF}_2:\text{Mn}$ as the phosphor, the device detects gamma-ray doses in the milliroentgen range and is linear in response up to at least 10^5 r. Dose readings can be made in less than a minute with simple instrumentation requiring no darkroom facilities. The dosimeter may be re-used many times. The response is independent of the dose rate at least over the range 10 mr/min - 7000 r/min. With suitable tin shields, the response is independent of energy over the range 40 keV - 1.25 MeV. The advantages of this device for monitoring of personnel in health physics operations are pointed out.

11,639 DOSIMETRY OF IONIZING RADIATION AND NEUTRONS WITH THE AID OF THERMOLUMINESCENCE by N. Haering and M. Schoen (Tech. Hochschule, Munich); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 541-548

The use of the thermoluminescence of powdered $\text{CaF}_2(\text{Mn})$ crystals to measure the dose of ionizing radiation in the range 1 mr - 10^4 r is discussed. The energy stored in irradiated samples is freed by heating and is emitted as luminescent visible radiation. In the range 1 mr to 10^4 r, the sum of the emitted light is proportional to the radiation dose. A dose exceeding 100 mr can be measured within 3 per cent and the reproducibility of the crystals is a very satisfactory 3 per cent. There are some difficulties, connected with triboluminescence, in measuring doses below 100 mr. These difficulties are considerably reduced by using conducting surface layers of SnO_2 on the $\text{CaF}_2(\text{Mn})$ grains. With Bi^{10} or Li^6 layers it is also possible to measure slow or moderated neutrons. With Li^6F layers the best results, with a lower limit of 5×10^3 neutrons/ cm^2 , were obtained.

INSTRUMENTATION (Cont'd)

11,640 SOLID-STATE NEUTRON-GAMMA DOSIMETER by B. Gross and P. Murphy (Inst. Natl. Tech., Brazil); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 549-554

A solid state neutron-gamma dosimeter is described. The device is so constructed that it combines the effects of a directed flux of gamma rays and of a directed flux of neutrons in insulators in such a way that it differentiates between neutrons and photons in a gamma-neutron field. A directed flux of gamma rays produces in an insulating scatterer a Compton electron current the intensity of which is proportional to the radiation flux. Similarly a directed flux of neutrons produces in a hydrogenated insulating substance a current of recoil protons which is a measure of the neutron flux.

11,641 GERMANIUM DOSIMETER FOR EVALUATION OF FAST NEUTRON DISTRIBUTION IN THE REACTOR CORE by J. Aleksandrowicz and M. Bartenbach (Inst. Badan Jadrowych, Warsaw); Selected Topics in Radiation Dosimetry, Intl. Atomic Energy Agency, 1961, pp. 639-641

The use of the fast-neutron induced gradual change in conductivity of n-type Ge to p-type to determine the relative fast neutron flux distribution within a reactor core is discussed. Parallelepiped-shaped Ge single crystals measuring $1.5 \times 1.5 \times 10$ mm with ohmic contacts were used. The crystals were n-type with large electron concentrations in the conduction band. In this material, the slope of the initial part of the plot of electrical conductivity vs time of fast neutron irradiation is a measure of the fast neutron flux. The influence of thermal neutrons is minimized by covering the Ge crystals with a Cd foil 0.25 mm thick. Flux distribution measurements can be made rapidly by means of a thin Al tube containing 9 Ge crystals mounted at equal distances within the tube. The tube is placed vertically within the core between the fuel elements. After an interval of time, the tube is lowered exactly the distance between two of the Ge crystals. The electrical conductivity is measured continuously under irradiation.

Pulse Height Analyzer - See 11,580

11,642 LINEAR COUNT-RATE METER by J. J. Henry (U.S. AEC); U.S. Pat. 2,999,168, Issued Sept. 5, 1961

An improved counting rate meter system is described. A series of input pulses are introduced into a pulse height discriminator which feeds a Schmitt trigger circuit where the pulses are converted into positive pulses of uniform width and amplitude. The trigger output pulses are fed into a one-shot multivibrator with variable pulse width control. The output of the multivibrator is then connected into a constant current metering source, which is electronically switched to an averaging circuit in response to each pulse received. The average current through an output meter is then equal to the product of the counting rate, the constant current, and the multivibrator pulse width. The meter will measure counting rates up to 100,000 cps with a substantially linear output. One application of the device would be to indicate the counting rate from a proportional radiation detector.

11,643 MINIATURE TRANSISTOR TIMERS by P. Mitchell (E.M.I.); Electronic Engrg. Vol. 33, p. 669, Oct. 1961

A transistor timing circuit capable of producing time delays in excess of five minutes is described. The timing circuit is an RC

network with an output stage biased to trigger when the charge on the capacitor reaches a predetermined level. An additional transistor is used to provide a constant charging current, increasing the time delay available without increasing the capacitor size. A variable resistor is used to provide the variable time delay.

OTHER APPLICATIONS

11,644 HIGH SPEED CIRCUIT BREAKERS by C. D. Todd (Hughes); Semicon. Prod., Vol. 4, pp. 31-34, Oct. 1961

A high speed circuit breaker, using the stable peak current of gallium arsenide tunnel diodes, which provides protection for overloads of 10 per cent or less is described. A transistor in series with the load is controlled by the bias voltage across a tunnel diode. For load currents below the limit value, the tunnel diode remains in the low voltage state and the transistor is in saturation. If the load current increases past the limit value the tunnel diode switches to the high voltage state, reducing the transistor drive and disconnecting the load from the supply. Tunnel diodes may be used in series to provide higher switching voltages. With additional circuitry, the breaker may be reset automatically when the overload is removed.

11,645 STATIC OVERCURRENT TRIPPING DEVICE FOR LOW-VOLTAGE BREAKERS by R. L. Winship (Allis-Chalmers); Electrical Engrg., Vol. 80, pp. 837-841, Nov. 1961

A static overcurrent tripping device employing semiconductors is described. A typical electromechanical trip device is shown in detail to give a basis for comparison with the static device. A block diagram is given describing the static overcurrent trip device. Three current transformers provide a small low-voltage secondary current proportional to the primary current. The secondary windings are connected to provide rectified power to operate the device trip coil and the transistor circuit, and to provide alternating output voltage which is applied to the sensing part of the device. Time-current characteristics of both the electromechanical and static trip devices are given. The advantages of static tripping devices are: simplified field testing, ease of changing the continuous-current rating of a breaker, reduced maintenance, greater flexibility in trip device characteristics, better co-ordination with fuses, relays and other protective equipment, and better over-all system and equipment protection through a more accurate trip device.

NEW PRODUCTS

MATERIALS AND DEVICES (Including Test and Fabricating Equipment)

11,646 INDIUM ARSENIDE (Merck and Co., Inc., Electronic Chemicals Division, Rahway, N. J.)

Polycrystalline Indium Arsenide ingots are now available with controlled Hall constants ranging from $10 \text{ cm}^3/\text{coulomb}$ to $300 \text{ cm}^3/\text{coulomb}$. Applications to date have been in Gauss meters, as active elements in watt-hour meters, and in the communication field as Hall modulators and isolators. The Hall constant of the material can be controlled to ± 10 per cent over a 5 in length ingot. Cross-section of the ingots is approximately $3/4$ by $1/2$ in.

11,647 PRECIOUS METALS FOR SEMICONDUCTORS (Engelhard Industries, Inc., 113 Astor St., Newark 2, N.J.)

Gold, silver, and the platinum group metals available as solid alloys, doped alloys, or clad to base metals are announced. These can be furnished as sheet, ribbon, rod, fine wire, or preforms. Clad material is available as single or double clad and inlays, and nearly all alloys can be clad to the following base metals: Molybdenum; Kovar; Rodar; nickel; 60 per cent iron - 40 per cent nickel; 70 per cent iron - 30 per cent nickel; tantalum; titanium; and copper.

11,648 VERTICAL CRYSTAL PULLER (Allen-Jones Inc., 1325 Baylond St., Long Beach 13, Calif.)

A Czochralski type vertical crystal puller is announced. Adaptable to RF or resistance heating of melt, it may be used to produce elemental and compound semiconductor materials. Den-drite growth experiments may be undertaken after slight modification. All mechanical assemblies are conveniently operated with the furnace tube visible and accessible from all directions. The apparatus has a pulling rate of from 1/4" per hour to 6" per minute; seed rotation varies from 5 to 55 RPM and pulling distance is to 25", which may be extended with adaptors. Over-all physical specifications are: 16" by 16" by 48" high, with a quartz furnace tube 48 mm in diameter and 14" long.

11,649 VACUUM EVAPORATOR FOR COATING APPLICATIONS (Vacuum Specialties, Inc., 34 Linden St., Somerville, Mass.)

A bell-jar vacuum evaporator (Series 2100; Model VSC-20) for use in thin-film deposition and as an environmental test system is announced. Allowing full and flexible operation from a single setting or standing position, this 32-inch desk-high console features electric hoisting of its shielded 18-inch diameter bell and provisions for introducing a wide combination of test currents and voltages. Exhausting to 2×10^{-5} mm Hg in 30 minutes, it will produce ultimate pressures in the 10^{-6} mm range. Applications include general laboratory use and small-parts production coating in the electronics, optics, infrared, and semiconductor fields.

11,650 LAPPING AND POLISHING SURFACE (Geoscience Instruments Corp., 110 Beekman St., New York 38, N.Y.)

A heavy-duty high density polishing chemotextile (Pellon PAD) is announced for use in production lapping and polishing. This semipermanent tool surface is affixed directly to any lap plate with the flatness of the lap subsurface transmitted to within a half-millionth of an inch to the PAD tool surface. Outwearing hard metal laps by a factor of four, it is claimed to drastically reduce costs in finishing silicon, germanium, ferrites, laser rods, quartz, and other electronic components.

11,651 MULTI-SCRIBER (Kulicke and Soffa Manufacturing Co., Inc., 401 North Broad St., Philadelphia 8, Pa.)

A high-speed precision multi-scriber (Model 720) for semiconductor wafer slices not having deposited geometrics is announced. Ruggedly constructed for controlled hydraulic operation, the machine has a 10 by 10 inch ground surface work area containing 25 standard 1 inch vacuum chucks. Five independent scribing heads are provided, each with over 2 inches of table traverse. The worktable may be rotated manually through 90 degrees. Featured are precise tool adjustment

and automatic indexing for dice sizes up to 0.400 inches. Speeds to 15 cycles per second at up to 12 inch stroke are obtained.

11,652 SEMICONDUCTOR LIFETIME TESTER (Electro-Impulse Laboratory, Inc., 208 River St., Red Bank, N.J.)

Semiconductor lifetime measuring equipment (Model LM-2) in a self-contained single package is announced. Requiring only a good scope, this tester will measure lifetimes as short as one microsecond. Ingots with 1 ohm resistivity can be measured without the use of a pre-amplifier, and large or small samples including cylindrical ingots can be accommodated. A stabilized spark gap to simplify measurements is featured.

11,653 THERMOELECTRIC POWER METER (Cambridge Systems, Inc., 621 Main St., Waltham 54, Mass.)

A thermoelectric power meter for the nondestructive determination of thermoelectric power and material homogeneity is announced. Profile measurements are made by applying a known and controlled thermal difference to the surface of the semiconductor, and simultaneously measuring the EMF developed. No sample preparation is required, and the measurement is generally insensitive to surface effects and crystal geometry.

11,654 ULTRA-FAST SWITCHING DIODE (Microwave Associates, Inc., Burlington, Mass.)

A high-speed silicon point contact computer diode (Model MA-4121) for applications requiring exceptionally fast switching speed and response is announced. Reverse recovery time is a fraction of a nanosecond and is governed primarily by wiring configuration. Junction capacitance measured at 0 volts bias is 0.50 pf (max.). Forward characteristics are 10.0 milliamps at 0.55 volts (max.), and 30.0 milliamps at 1.0 volts (max.). Maximum reverse current is 200 microamps at -4 volts. The unit is packaged in a standard subminiature glass case of .105" diameter and .300" length.

11,655 SILICON CONTROLLED RECTIFIER (General Instrument Corp., Semiconductor Division)

A 16 amp., 500 volt all diffused silicon controlled rectifier is announced. Formerly, silicon controlled rectifiers have been produced by diffusing two opposite layers of "P" silicon on the surfaces of an "N" slice where the final "N" junction has been formed by alloying. In this case, the alloyed junction has been replaced with diffusion, providing a "triple diffused" device. Offered in standard JEDEC ratings from 2N681 (25 PIV) to 2N689 (500 PIV), these rectifiers feature: high reliability, stability at ambient temperatures to 125°C, lower turn-on voltage and current requirements, and lower forward voltage drop.

11,656 RECTIFIER TESTER (Power Sources, Inc., Northwest Industrial Park, Burlington, Mass.)

A silicon control rectifier tester priced lower than any such unit presently available is announced. Supplied with all necessary attachments for complete operation, the unit will test forward and reverse leakage, gate voltage and gate current. Zener and most other diodes can be tested for breakdown voltage, reverse current, and drift. Rectifiers can be tested for leakage and PIV.

MATERIALS AND DEVICES (Cont'd)

11,657 SWITCHING TRANSISTORS (Philco Corp., Lansdale Division, Lansdale, Pa.)

Silicon precision alloy transistors (SPAT) are announced. The T-2363, and the matched pair T-2357, are capable of operating at collector (V_{ce}) and emitter (V_{be}) voltages of 30 volts each with leakage current (at 65°C) of 15 nanoamps maximum. They are specifically designed for application in high-accuracy electronic choppers, multipliers, demodulators, and other high resolution low level switching circuits.

UNITS AND SYSTEMS

11,658 UNIT OSCILLATORS (Burr-Brown Research Corp., Box 6444, Tucson, Ariz.)

A series (No. 1391) of transistorized unit oscillators providing high quality sine waves of fixed frequency is announced. Available in frequencies from 1 cps to 100,000 cps, these plug-in units show distortion of less than 0.1 per cent, amplitude stability of 0.05 per cent per °C, and frequency stability of 0.01 per cent per °C. Each oscillator is packaged in a 1" by 2.6" by 3.6" module.

11,659 RADIO CONTROL RECEIVER (Otarion Electronics, Inc., P.O. Box 711, Ossining, N.Y.)

A postage-stamp sized, fully-transistorized radio control re-

ceiver weighing less than a half ounce is announced. Said to be the world's smallest, this battery-powered receiver has a synchro tuning indicator built into its printed circuit and is temperature compensated from zero to 120°F. Power is 15 ma nominal, no carrier and 4 ma nominal with carrier. Frequency range extends to all 27 megacycle citizen band channels.

11,660 HUMIDITY READER AND CONTROLLER (Phys-Chemical Research Corp., 40 East 12th St., New York 3, N.Y.)

A fully-transistorized instrument (Hygrocon-1) for the accurate reading and regulation of critical humidity environments is announced. Designed to operate with either of two composite sensing units offered conjunctively, the device will control to within a fraction of 1 per cent RH throughout the entire relative humidity range. Differential control with independently adjustable high-low limits, and a total of five RH per cent monitoring scales are among those features offered.

11,661 RADIATION MONITOR (Radiation Equipment and Accessories Corp., 665 Merrick Road, Lynbrook, N.Y.)

A compact, transistorized personnel protection unit (Scram I) which warns of radiation danger by producing an audible chirping noise is announced. Sounding like a cricket, this tiny, 3.5 ounce pen-type dosimeter can be carried in the breast pockets of laboratory and industrial workers and will operate continuously for one year on a single mercury battery. The device has no switch and provides its own internal check by chirping once every two minutes at normal background levels. Chirping frequency increases with radiation intensity such that at one Roentgen per hour, sound frequency is about 2,800 cycles per second.

SUBJECT INDEX

A

A^{II}B^{VI} Solid Solutions 11,261

A^{III}B^V:

Compounds, Phase Diagrams of 11,257

Solid Solutions 11,265

A^{III}B^V-A^{III}B^{VI} Compounds 11,255, 11,258

A^{II}B^V-A²III^{B₃VI} Compounds 11,255, 11,256

A²V^{B₃VI} Compounds, Phase Diagram of 11,252

Absorbance of Single Crystal Sb, Infrared 11,437

Absorption:

in BaTiO₃, Color Center 11,432

in CdS,

Effect of Metallic Impurities on 11,439

Ultraviolet 11,442

Edge, Correlation of Edge Luminescence with 11,450

Edge of GaSb-InSb Alloys 11,335

Spectra of:

Alkali Halide Phosphors, Effect of Pressure and Temperature on 11,430

Alkali Halides, Origin of K- and L-Bands in the 11,434

NaCl and KCl Crystals with Pb Impurity 11,363

Spectrum in LiF 11,464

in SrF₂, Color Center 11,433

Accelerometers 11,632

Activation:

Energies in Ga₂Te₃ and In₂Te₃ 11,371

Energy of:

A^{II}B^{VI}-A²III^{B₃VI} Compounds 11,457

Binary III-VI Alloys 11,457

Adder, Tunnel Diode Module 11,617

Addition Agents in Electrodeposition, Analysis of Mechanism of 11,329

Address System, Digital Differential Analyzer 11,618

Airborne:

Distance Measuring:

Equipment, Pulse Selector for 11,590

Equipment: 11,589

System, Transistorized 11,592

Receiver for the DME System, Transistor 11,591

Alkali Halide Lattices, Activation and Relaxation Energies for Interstitial Neutral Defects in 11,283

Alkali Halides,

Absorption Spectra and Conductivity of 11,363

Origin of K- and L-Bands in the Absorption Spectra of 11,434

Alloyed p-n Junctions, Technique for Forming 11,500

Alloying Control by Dislocations 11,488

Alloys,

Binary: Reference Data on 11,248

Effects of Disorder in Semiconductor 11,331

Aluminum, Al²⁷ Nuclear Spin System in 11,424

Aluminum Antimonide and Gallium Antimonide/Indium Antimonide, Formation of Mixed Crystals of 11,264

Aluminum Antimonide-Aluminum Telluride System, Solid Solution in 11,269

Aluminum Antimonide-Gallium Antimonide System, Energy Gaps in the 11,268

Solid Solutions in the 11,268

Amorphous Semiconductors, Properties of 11,332

Amplifier Module, Video: Transistor 11,542

Amplifiers,

AGC in Audio 11,536

Feedback in: Computer Analysis of 11,540

HF: Tunnel Diode 11,550

Integrating: Transfluxor 11,544

Magnetic 11,518, 11,556

Microwave Maser 11,527

Noise in 11,539

Parametric: 11,549

Integrated Multistage 11,490

L-Band Traveling Wave 11,548

Low Frequency Pump 11,546

Three Signal Frequency 11,547

Power: Linear 11,554

Pulse: 11,575

Nonsaturating 11,543

Transistor: Characteristics of High Frequency 11,493

Tunnel Diode:

Coupling in 11,552

L-Band 11,551

Noise Figure of 11,538

Amplitude Comparator 11,565

SUBJECT INDEX (Continued)

- annealing of Quenched-in Extra Resistivity in Au Wires 11,364
- antennafiers, Design of 11,597
- antennaversers, Design of 11,597
- antiferromagnetic:
- Domains in MnF_2 , Absence of 11,413
 - MnF_2 , Resonance Shift in 11,414
- antiferromagnetism in:
- $LaCrO_3$ 11,412
 - $MnHg$ 11,411
- antiferromagnets, Magnetic Properties of 11,410
- antimony, Infrared Absorbance of 11,437
- arming-Fuzing Timer for Atomic Artillery Missile 11,594
- automatic Gain Control, Audio Amplifier 11,536
- automation, Digital Control of Machine Tool 11,624
- automation of Machine Tools, Servo Systems for 11,625
- avalanche Transistors, Theory and Applications of 11,498
- B
- Bardeen-Cooper-Schrieffer Correlation Functions for Superconductivity 11,379
- barium Titanate,
- Absorption by Color Centers in 11,432
 - Domain Motion in 11,349
 - Domains in 11,348
 - Ferroelectric Theory of 11,346
- barium Tungstate, Growth of 11,321
- barrier Layers at Metal-Semiconductor Contacts 11,460
- beryllium Crystals, Electrical Properties of Ge 11,429
- binary Alloys,
- Reference Data on 11,248
 - Review of Semiconductor 11,246
 - X-Ray and Slow Neutron Analysis of 11,247
- bismuth, Surface Resistance Measurements in 11,395
- bismuth Telluride, Mobility of Holes and Electrons in Solid Solutions Based on 11,356
- bismuth Telluride Alloys, Thermal Conductivity of 11,516
- bismuth Telluride-Bismuth Selenide Alloys, Optical Energy Gap of 11,336
- blestable Trigger, High Speed 11,562
- black Walls,
- Excitation Spectrum of Electronic Spins in 11,425
 - NMR in 11,425
- blocking Oscillator 11,560
- band Structure in Wurtzite-Type Lattice, Analysis of 11,279
- bands in $A_{II}B_{VI} - A_{II}B_{VI}$ Compounds 11,262
- barrier by Floating Zone Method, Preparation of 11,301
- boxcar Circuits 11,568
- rain Potentials, Implanted Device for Measurement of 11,585
- broadband Resonance Absorption Characteristics, Ferrites with 11,305
- C
- cadmium, Pressure Dependence of Electrical Resistance of 11,360
- cadmium Antimonide, Physical Properties of 11,436
- cadmium Nickel Ferrites, Low Resistivity and Low Dielectric Constant 11,312
- cadmium Sulfide,
- Current Density Distribution in 11,368
 - Effect of Metallic Impurities on Absorption in 11,439
 - Elastic Constants of 11,472
 - Linear Compressibilities of 11,472
 - Photoconduction in 11,455
 - Photoelectric Effects in 11,512
- Thermostimulated Current Curves of Irradiated 11,367
- Ultraviolet Absorption in 11,442
- cadmium Sulfide Spectrophotometer 11,455
- cadmium Telluride-Zinc Telluride Alloys, Conductivity and Photoconductivity of 11,376
- cadmium Tungstate, Growth of 11,321
- calcium Fluoride, Fluorescence of 11,451
- calcium Sulfate, Proton Nuclear Spin System in 11,424
- calcium Tungstate,
- Growth of 11,321
 - Spectral Diffusion in the PMR of Ce^{3+} and Er^{3+} in 11,428
- Carbon Aggregates, Effect of Heat Treatment on the Electrical Resistance of Granular 11,365
- Carrier:
- Equipment, Power Supply for 11,600
 - Properties of:
 - $A_{II}B_{VI}$ Compounds 11,373
 - GaAs, Temperature Dependence of 11,359
 - Ga_2Te_3 and In_2Te_3 11,371 - Recombination in Semiconductors, Theory of 11,350
- cascaded Emitter Followers, Low-Frequency Instability in 11,553
- Cerium-Activated Glasses for Scintillation Counters 11,633
- Cerium $^{3+}$ in $CaWO_4$, Spectral Diffusion in the PMR of 11,428
- Cesium Antimonide, Photovoltaic Effect in 11,459
- Characteristics of:
- Diodes, Effect of Deep Impurities on the I-V 11,481
 - HF Transistors 11,493
 - Reverse Biased Diodes, Small-Signal 11,486
- Chromium, Electronic Structure of the 3d Band in 11,341
- Chromium $^{3+}$, PMR of 11,419
- Chromium Bromide, NMR Determination of Temperature Dependence of the Magnetization of 11,401
- Chromium-Iron Alloys, Specific Heat and Debye Temperature of 11,468
- Circuit:
- Breaker, High Speed 11,644
 - Breakers, Static Overcurrent Tripping Device for Low Voltage 11,645
- Clippers 11,584
- Clock Pulse Generators, Tunnel Diode-Transistor 11,611
- Cobalt Films,
- Ferromagnetic Resonance of 11,409
 - Preparation and Properties of Plated 11,327, 11,399
- Cobalt-Nickel Platings, Structure and Magnetic Properties of 11,308
- Cobalt Oxide, Hyperfine Structure of Divalent and Trivalent Fe^{57} in 11,417
- Cobalt-Phosphorus Films, Preparation and Properties of Plated 11,306
- Color Center Absorption:
- in $BaTiO_3$ 11,432
 - Spectra of Alkali Halides 11,434
 - in SrF_2 11,433
- Communications System, Digital Data 11,604
- Comparator 11,566, 11,567
- Comparator,
- Minimum-Amplitude 11,565
 - Pulse Height 11,580
- Compensating Network Design 11,528
- Compressibilities of CdS , Linear 11,472
- Computer:
- Analysis of Feedback in Amplifiers 11,540
 - Circuitry - See Specific Circuit
 - Code for the Determination of Lattice Parameters 11,278
- Conduction Bands in Ge 11,362
- Conductivity:
- of $A_{II}B_{VI}$ Compounds 11,373
 - of Bi_2Te_3 Alloys, Thermal 11,516
 - in $CdSb$, Anisotropic 11,436
 - of $CdTe-ZnTe$ Compounds 11,376
 - of GaAs, Temperature Dependence of 11,359
 - of Ga_2Te_3 and In_2Te_3 11,371
 - in Ge, Pressure Dependence of 11,362
 - of $In(As, P_{1-y})$ 11,396
 - of Mg-Ge-Sn Compounds 11,377
 - of NaCl and KCl Crystals with Pb Impurity 11,363
 - in Organic Compounds, Dark 11,456
 - of $Te_2Sb_2Se_4$ 11,374
- Contacts to Si, Formation of Surface 11,489
- Controlled:
- Rectifier, Si Diffused 11,655
 - Rectifier Test Set 11,656
- Converters,
- dc 11,598
 - Telephone Carrier Power 11,600
 - Voltage to Frequency 11,570
- Cooling of Thermal Detectors, Force Cycled 11,517
- Copper,
- Cyclotron Resonance in 11,390
 - Epitaxial Growth and Twinning in 11,295
 - Recombination of Interstitials with Vacancies in 11,282
- Cores,
- Mg-Mn Ferrite 11,521
 - Preparation of Ferrites for High Frequency 11,310
- Cores with Interleaved Lamination Stacks, Magnetic 11,519
- Counters,
- Binary: Tunnel Diode-Transistor 11,611
 - Decimal 11,616
 - Tunnel Diode 11,563
- Counting Rate Meter 11,642
- Coupling in Tunnel Diode Amplifiers 11,552
- Cryogenic Devices 11,530
- Crystal Structure of:
- Gallium Chalcogenides 11,297
 - HgSe and HgTe 11,357
 - InSb-InTe Alloys 11,258
- Cupric Oxide, Stark Exciton Effect in 11,431
- Current Gain, Fabrication of Ge Alloy Junction Transistors Having High 11,503
- Cyclotron Resonance in:
- Cu 11,390
 - Deformed InSb, Ge and Si Crystals 11,420
- Czochralski:
- Crystal Puller 11,648
 - Method, RF Heating in Crystal Growth by 11,298
- D
- dc:
- Converter, TV 11,598
 - Supply for Vacuum Tube Heaters, Stabilization of 11,620
 - Voltage Regulators 11,621
- Debye Temperature of:
- $Cr_{80}Fe_{19.4}$ 11,468
 - Ge 11,465
- Defects in:
- Alkali Halide Lattice, Relaxation and Activation Energies for Interstitial Neutral 11,283
 - Ge, γ -Ray 11,339
- Deformed Crystals, Resonance in 11,420
- Dendrites, Feasibility of Junction Diodes on GaAs 11,491
- Desiccants for Use in Transistors and Diodes, Metallic 11,509
- Detectors,
- Fabrication and Properties of HgSe Infrared 11,513
 - Forced Cycled Cooling of Thermal 11,517
- Device Fabrication Techniques 11,533

SUBJECT INDEX (Continued)

- Devices, Packaging and Encapsulation of Semiconductor 11,507
- Dicing Machine 11,651
- Dielectric:
Constant of LiF 11,464
Properties of Irradiated Polyethylene 11,344
- Dielectrics, Thermal and Electrical Properties of 11,345
- Diffraction by fcc Crystals with Deformation Faults 11,280
- Diffusion, Gettering of Impurities during 11,289, 11,290
- Diffusion:
Control by Dislocations 11,488
Controlled Mechanism of Electroless Ni Plating 11,328
of P in Si, Open Tube 11,291
- Digital:
Analog Converter 11,623
Circuits, High-Speed 11,611
Control of Machine Tools 11,624
- Diode, Point Contact: High-Speed 11,654
- Diode Test Set 11,656
- Diodes - See also Tunnel Diodes
- Diodes,
Effect of Deep Impurities on I-V Characteristics of 11,481
- Junction:
Dendritic GaAs 11,491
GaP 11,482
High Frequency Diffused 11,490
Oxidation-Induced Degradation of the Reverse Characteristics of Diffused 11,483
Reverse Characteristics of Ge 11,484
Masking Techniques for Diffused 11,504
Measurement of Thermal Parameters of Power 11,487
Metallic Desiccants for Use in 11,509
Small-Signal Characteristics of Reverse Biased 11,486
- Direct Coupled Amplifier for Small Currents 11,555
- Discoloration Spectra of SrF_2 11,433
- Dislocation Etch Pits in PbTe, Non-[100] 11,324
- Dislocations, Control of Alloying and Diffusion Properties by 11,488
- Dislocations in:
Ge Grain Boundaries 11,286
InSb, Etch for Revealing Sb Edge 11,325
Ionic Crystals, Charged 11,285
Lattices, Methods of Generation and Effect of 11,284
- Disorder in Semiconductor Alloys, Effects of 11,331
- Distance Measuring Equipment, Airborne 11,589, 11,590, 11,591, 11,592
- Divacancies in Si by Electron Irradiation, Production of 11,281
- Domain:
Motion in BaTiO_3 11,349
Wall Detection 11,414
- Domains in:
 BaTiO_3 11,348
 MnF_2 , Absence of Antiferromagnetic 11,413
- Doping, Diffusion Method of Semiconductor 11,290
- Dosimeters,
 γ - and X-Radiation 11,514
Metaphosphate Glass γ -Ray 11,637
Neutron- γ 11,640
Phosphate Glass Neutron 11,636
Thermoluminescent γ -Ray 11,638
Transistorized 11,661
- Dosimeters for Determining Neutron Flux Distribution in Reactor Cores, Ge 11,641
- Dosimetry of Ionizing Radiation and Neutrons by Means of Thermoluminescence 11,639
- Dot Component Application in Electronic Packaging 11,532
- Down Converter, Tunnel Diode 11,571
- Drift Transistors,
Fabrication of 11,497
Method for Improving Characteristics of 11,496
- E
- Eddy Current Loss in Magnetic Materials, Temperature Dependence of 11,403
- Edge Luminescence of As_2S_3 , Si_2O_2 , V_2O_3 , MoO_3 11,450
- Effective Mass of:
CdSb, Hole 11,436
GaAs 11,359
Ge, Electron 11,465
- Elastic:
Constants of CdS 11,472
Properties of the Wurtzite and Zincblende Lattices 11,473
- Electrical Properties of:
Crystals, Effect of Dislocations on 11,284
Dielectrics 11,345
- Electrodeposition, Analysis of Mechanism of Addition Agents in 11,329
- Electrodeposition of:
Co:
Films 11,327
and Ni Films 11,399
Co-P Films 11,306
Molten Metals and Alloys on Leads 11,326
Ni-Fe Films, Magnetic Field 11,309
- Electrodeposits,
Measurement of Stress in 11,471
- Electrodes, Attaching Semiconductor Device 11,506
- Electroless Plating of Ni, Effect of Pressure on 11,328
- Electroluminescence, Effect of Particle Interaction on 11,447
- Electroluminescence:
of Evaporated ZnS 11,445
from GaP Diodes 11,482
at Low Voltages 11,445
of ZnS, Effect of Cu and Mn Activators on 11,446
in ZnS (Cu, Al) Phosphors by Ultraviolet Radiation, Enhancement of 11,444
- Electron:
Distributions in KMnF_3 , KFeF_3 , KCoF_3 , and KNiF_3 11,343
Effective Mass in Ge 11,465
Irradiation, Production of Divacancies in Si by 11,281
Scattering in Ge 11,330
Spin Resonance of:
Electron Excess Centers in KCl 11,421
an Irradiated Single Crystal of Urea Oxalate 11,422
X-Irradiated Single Crystals of Rochelle Salt 11,423
- Electronic:
Packaging, Thermal Design in 11,535
Structure of the 3d Band in Cr 11,341
- Electrons in Cubic Semiconductors, Field Dependence of the Mobility of Warm 11,353
- Emitter Followers, Low-Frequency Instability in Cascaded 11,553
- Encapsulation of Semiconductor Devices 11,507
- Encoder, PCM 11,602
- Energy:
Band Structure of:
Bi 11,395
Ge-Si Alloys, Reflection Spectra Determination of 11,334
In ($\text{As}_x\text{P}_{1-x}$) 11,396
Semiconductors 11,331
Te 11,391
- Gap of:
 Bi_2Se_3 - Bi_2Te_3 Alloys 11,336
CdSb 11,436
GaSb-InSb Alloys 11,335
 Ga_2Te_3 and In_2Te_3 11,371
Ge-Si:
Alloys 11,337, 11,369
Alloys, Concentration Ratio Dependence of 11,333
Te-Se Alloys, Se Concentration Dependence of 11,370
- Gaps:
of A IIIbV Compounds 11,388
in the AlSb-GaSb System 11,268
Level Model for High Resistivity GaAs 11,340
- Levels of:
CdS 11,367
 γ -Irradiated Ge 11,339
- Transfer in a Nuclear Spin System, Double Magnetic Resonance Technique for Studying 11,424
- Epitaxial:
Growth of Noble Metals on LiF and Mica 11,295
Junction Transistors, Fabrication of 11,501
- Equivalent:
Circuit, Tunnel Diode 11,479, 11,550
Circuit of Transistor, Thermal 11,499
- Error Detecting Circuit, Parity Check 11,613
- Etch:
for Examination of Junctions in Si, Staining 11,299
Pits in PbTe, Non-[100] Dislocation 11,324
for Revealing Sb Edge Dislocations in InSb 11,325
- Etching:
Characteristics of:
GaP Crystals 11,302
InSb {111} Surfaces 11,325
of Electrolytically-Polished PbTe 11,324
Europium Oxide, Ferromagnetic 11,415
Europium³⁺ in CaWO_4 , Spectral Diffusion in the PMR of 11,428
Eutectic Formation for Si Surface Contacts, Gold-Silicon 11,489
- Evaporator 11,649
- Exciton Effect in Cu_2O 11,431
- F
- F-Center Spin Resonance, Optical Saturation of 11,440
- Fabrication Techniques, Device 11,533
- Face Center Cubic Crystals, X-Ray Diffraction by Deformed 11,280
- Faraday:
Ellipticity in Semiconductors on Scattering Mechanisms, Dependence of 11,463
Rotation in n-Type Ge 11,462
- Feedback:
in Amplifiers, Computer Analysis of 11,540
Systems for Machine Tool Automation 11,625
- Fermi Level of GaAs, Temperature Dependence of 11,359
- Ferric Oxide, Preparation of Pure 11,311
- Ferrimagnetic Garnets, Preparation of 11,319
- Ferrite:
Components for UHF and Microwave Systems 11,605
Cores, Mg-Mn 11,521
- Ferrites,
Low Resistivity and Low Dielectric Constant Cadmium Nickel 11,312
Preparation of Mn-Zn 11,313
- Ferrites:
with Broadband Resonance Absorption Characteristics 11,305
for High Frequency Cores, Preparation of 11,310

SUBJECT INDEX (Continued)

- with High:
 - Initial Permeabilities and Low Magnetic Losses, Preparation of 11,315
 - Permeability, Mn 11,522
 - for Permanent Magnets 11,316
 - from Pure Fe_2O_3 , Preparation of 11,311
 - with Temperature-Independent Permeability, Preparation of Mn-Zn 11,314
 - piezoelectric:
 - $\text{C}(\text{NH}_2)_3 \cdot \text{Al}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$, Reorientation of the Guanidium Ion in 11,347
 - Theory of Ba_2TiO_3 11,346
 - ferromagnetic:
 - EuO 11,415
 - Films,
 - Interaction of Phonons and Magnons in Thin 11,407
 - Torque Measurement of Magnetic Anisotropy of 11,405
 - Rare Earth Oxide 11,415
 - Resonance in Co Films 11,409
 - Spin Lattice Relaxation Time in YIG 11,408
 - field Effect:
 - Studies of Semiconductor Surface Phenomena 11,392
 - Transistors,
 - Fabrication of 11,511
 - High Frequency 11,510
 - Film Structure, Ge 11,294
 - Films,
 - Composition and Thickness Effects on the Magnetic Properties of Electrodeposited Ni-Fe 11,397
 - Magnetic Field:
 - Dependence of the Superconducting Penetration Depth in Thin 11,384
 - Electrodeposition of Ni-Fe 11,309
 - Measurement of Stress in 11,471
 - Preparation and Properties of Plated:
 - Co 11,327
 - Co-P 11,306
 - Ni and Co 11,399
 - Structure:
 - and Magnetic Properties of Plated Co-Ni 11,308
 - of Noble Metal 11,295
 - superconductivity in 11,382
 - Transition Temperatures of Superconducting 11,383
 - films:
 - of Fe-Ni, Structural Properties of 11,307
 - on Semiconductor Surfaces, Measurements of Thickness and Refractive Index of Oxide 11,322
 - of Tin on Gold, Transition Temperatures of Superconducting 11,385
 - filters, Active Low-Pass 11,583
 - floating Zone, Solid-Liquid Interface during Growth of Si Crystals by 11,299
 - fluorescence of $\text{CaF}_2:\text{Sm}^{2+}$ 11,451
 - flux Quantization in a Superconducting Tube 11,381
 - vortexoid in Superconductivity, Quantization of the 11,382
 - Forbidden Band Width:
 - in $\text{AIII}(\text{BVI}-\text{A}_2\text{III})\text{B}_3\text{VI}$ Compounds 11,457
 - in Binary III-VI Alloys 11,457
 - of Ge, Determination of 11,484
 - Fourier Transform Generator 11,578
 - frequency:
 - Cut-off, Method for Increasing Transistor 11,496, 11,502
 - Divider 11,572
 - Limitations of Tunnel Diodes 11,479
 - Meter, Wein Bridge 11,627
 - Spectra of Lattice Vibrations 11,342
 - action of NaCl and LiF, Measurement of Internal 11,476
 - size, Atomic Artillery Missile 11,594
- G
- Gadolinium Iron Garnet, Spontaneous Magnetization and Paramagnetic Susceptibility of 11,402
 - Gain, Method for Increasing Transistor Current 11,496
 - Gallium Arsenide Dendrite Junction Diodes, Feasibility of 11,491
 - Gallium Chalcogenides, Crystal Structure of 11,297
 - Gallium Antimonide, Phase Diagram of 11,253
 - Gallium Antimonide and:
 - Indium Antimonide, Solid Solutions of 11,263
 - Indium Antimonide/Aluminum Antimonide, Formation of Mixed Crystals of 11,264
 - Gallium Antimonide-Indium Antimonide Alloys,
 - Absorption Edge of 11,335
 - Optical Energy Gap of 11,335
 - Preparation of 11,335
 - Gallium Arsenide,
 - Energy Level Model for High Resistivity 11,340
 - Physical Properties of 11,359, 11,372
 - Gallium Arsenide:
 - with Gallium Antimonide/Indium Arsenide, Solid Solutions of 11,263
 - and Gallium Selenide, Solid Solutions of 11,266
 - and Indium Arsenide, Solid Solutions of 11,265
 - Gallium Arsenide-Gallium Phosphide Alloys, Energy Gaps of 11,338
 - Gallium Phosphide,
 - Luminescence in 11,449
 - p-n Luminescence and Photoluminescence in Zn-Doped 11,448
 - Gallium Phosphide:
 - Crystals, Growth and Etching Characteristics of 11,302
 - Diodes, Fabrication and Characteristics of 11,482
 - Gallium Selenide with ZnSe, Solid Solutions of 11,262
 - Gallium Telluride, Properties of 11,371
 - Gallium Telluride:
 - and In_2Te_3 , Solid Solutions of 11,267
 - with ZnTe, Solid Solutions of 11,262
 - Galvanomagnetic:
 - Coefficients of Te 11,391
 - Phenomena, Quantum Theory of Transverse 11,387
 - Gamma-Irradiated Polyethylene, Dielectric Properties of 11,344
 - Gamma-Radiation Detectors, Development of 11,514
 - Gamma-Ray Dosimeters,
 - Metaphosphate Glass 11,637
 - Thermoluminescent 11,638
 - Garnets, Sintering Method for Preparation of 11,303
 - Garnets with High Magnetic Moments, Ferromagnetic 11,319
 - GASH, Reorientation of the Guanidium Ion in Ferroelectric 11,347
 - Generation of Carriers in Semiconductors 11,350
 - Generators,
 - Fourier Transform 11,578
 - Pulse: Regenerative 11,575
 - Sawtooth 11,576
 - Square Wave 11,577
 - UHF Power 11,573
 - Germanium,
 - Debye Temperature of 11,465
 - Determination of Forbidden Band Width in 11,484
 - Effect of Humidity on Surface Recombination in 11,352
 - Electron:
 - Effective Mass in 11,465
 - Scattering in 11,330
 - Faraday Rotation in 11,462
 - Field Dependence of the Mobility of Warm Electrons in 11,353
 - Gamma-Radiation Defects in 11,339
 - Impurity Gettering during Diffusion in 11,289
 - Pressure Dependence of Conductivity in 11,362
 - Resonance in Deformed 11,420
 - Specific Heat of 11,465
 - Surface Recombination Centers in 11,351
 - Temperature and Magnetic Field Dependence of the Magnetoresistance of 11,389
- Germanium:
- Bicrystals, Properties of and Photocells Employing 11,429
 - Binary Systems, Analysis of 11,254
 - Dosimeter for Determining Neutron Flux Distribution in Reactor Cores 11,641
 - Double Crystals 11,286
 - Films, Textural Properties of 11,294
 - Single Crystals, Mosaic Structure in 11,287
 - Surfaces, Damaged Layer in Abraded 11,323
 - Germanium-Silicon Alloys,
 - Concentration Ratio Dependence of the Energy Gap of 11,333
 - Electrical Properties of 11,369
 - Properties of 11,337
 - Reflection Spectra of 11,334
 - Germanium-Silver Alloys, Formation of 11,259
 - Gettering of Impurities during Diffusion 11,289, 11,290
 - Glasses for Scintillation Counters, Cerium-Activated 11,633
 - Gold, Epitaxial Growth and Twinning in 11,295
 - Gold Wires, Annealing of Quenched-in Extra Resistivity in 11,364
 - Grain:
 - Boundaries, Dislocations in Ge 11,286
 - Boundary Photocells, Ge 11,429
 - Graphic Analysis of Nonlinear Circuits 11,529
 - Group:
 - III-V Ternaries, Phase Diagrams of 11,257
 - V-VI-VII Compounds,
 - Photoconductivity 11,458
 - Preparation of 11,458
 - Grown Junctions, Determination of Properties of 11,501
 - Growth of:
 - Boron by Floating Zone Method 11,301
 - Crystals by Czochralski Method, RF Heating in 11,298
 - GaP Crystals 11,302
 - Lithium Fluoride Whiskers 11,300
 - Si Crystals by Floating Zone, Solid-Liquid Interface during 11,299
 - Tungstate Paramagnetic Crystals 11,321
 - Yttrium-Iron-Garnet Large Single Crystals 11,318
- H
- Half-Bridge Inverter Supply for Three-Phase Power 11,622
 - Hall:
 - Coefficient of:
 - GaAs 11,372
 - Ge-Si Alloys 11,369
 - Te and Te-Se Alloys 11,370
 - Constant:
 - in GaAs, Temperature and Magnetic Field Dependence of 11,359
 - of In ($\text{As}_y\text{P}_{1-y}$) 11,396
 - Effect:
 - in $\text{AIII}(\text{BVI}-\text{A}_2\text{III})\text{B}_3\text{VI}$ Compounds 11,373
 - Devices, Magnetic Measurements with 11,629
 - in Ga_2Te_3 and In_2Te_3 11,371
 - Mobilities, Measurement of 11,355
 - Mobilities of Epitaxial PbS Films 11,354
 - Heat Dissipation of Rectifiers, Assembly for 11,492
 - High Density Electronic Packaging-Thermal Design 11,535

SUBJECT INDEX (Continued)

- High Frequency:
 Amplifiers, Tunnel Diode 11,550
 Diodes, Fabrication of 11,490
 Steering Circuit 11,569
 Transistors 11,493
- High-Speed Point Contact Diode 11,654
- Hole Effective Mass in CdSb 11,436
- Holmium, Nuclear Specific Heat of 11,466
- Humidity:
 Control and Sensing Unit 11,660
 on Surface Recombination, Effect of 11,352
- Hydrogen on the Magnetization of Nickel Particles,
 Effect of Chemisorbed 11,398
- Hysteresis:
 Loss in:
 Magnetic Materials, Temperature Dependence
 of 11,403
 Ni Films, Torque Measurements of 11,404
 in $Mn_{0.75}Co_{0.05}Fe_{1.2}O_4$, Magnetic 11,416
- I
- Imperfections:
 in Metal, Semiconductor and Ionic Lattice
 11,284
 on X-Ray Diffraction, Effect of Crystal 11,280
- Impulse Timing Chains 11,579
- Impurities:
 during Diffusion, Gettering of 11,289
 in Diodes on I-V Characteristics, Effect of Deep
 11,481
 in Semiconductors, Determination of 11,288
 from Semiconductors, Removal of Fast Diffusing
 11,290
 on Si Surfaces, Melting Point Depression by
 11,274
- Increment Store for Digital Differential Analyzer
 11,618
- Indium Antimonide,
 Etch for Revealing Sb Edge Dislocations in
 11,325
 Phase Diagram of 11,253
- Indium Antimonide-Indium Telluride Alloys, Crystal
 Structure of 11,258
- Indium-Antimony-Tellurium System, Semiconducting
 Compound of the 11,258
- Indium-Arsenic-Phosphorus Compounds, Electrical
 Properties of 11,396
- Indium-Arsenic-Selenium Alloys 11,256
- Indium Arsenide, Resonance in Deformed 11,420
- Indium Arsenide:
 and Indium Antimonide, Solid Solutions of
 11,263
 and Indium Telluride, Solid Solutions of 11,270
 Polycrystals, Availability of 11,646
- Indium Arsenide-Indium Antimonide, Phase Diagram
 of 11,249
- Indium Arsenide-Indium Phosphide Alloys, Energy
 Gaps of 11,338
- Indium Phosphide, Preparation and Crystal Structure
 of 11,292
- Indium Phosphide and Indium/Indium Arsenide,
 Formation of Mixed Crystals of
 11,264
- Indium Selenide, Phase Transition of 11,276
- Indium Selenide in Zincblende Structure Compounds,
 Solid Solubility of 11,271
- Indium Sulfide, Structure of 11,296
- Indium Telluride,
 Properties of 11,371
 Structure of 11,296
- Infrared:
 Absorptance of Single Crystal Sb 11,437
 Circuits in Tiras Satellites 11,630
 Detectors, Fabrication and Properties of HgSe
 11,513
 Irradiation in ZnS:Cu Phosphors, Effect of 11,443
 Luminescence in Tunnel Diodes 11,480
 Transmittance of:
 $SrTiO_3$ 11,435
 Y_2O_3 11,438
- Instability in Cascaded Emitter Followers 11,553
- Integrated Devices, Grown Single Crystal 11,530
- Integrating Magnetic Amplifiers, Transfluxors as
 11,544
- Interferometry,
 Decimal Counters for 11,616
 Measurement of Properties of Semiconductor
 Surface Oxide Films by 11,322
- Interstitial Neutral Defects in Alkali Halide Lat-
 tices, Activation and Relaxation
 Energies for 11,283
- Interstitials with Vacancies in Cu, Recombination
 of 11,282
- Inverter, Half-Bridge Transistor 11,622
- Ionic Crystals, Charged Dislocations in 11,285
- Ionization Chamber, Solid State 11,635
- Iron⁵⁷ in CoO, Hyperfine Structure of Divalent and
 Trivalent 11,417
- Iron-Nickel Electrodeposited Films, Magnetic and
 Structural Properties of 11,307
- Iron-Nickel Films, Preparation and Properties of
 Plated 11,309
- Isomorphism in:
 A^{II}B^{VI} Compounds 11,261
 A^{II}B^{VI} - A^{III}B^{3VI} Compounds 11,262
 A^{III}B^{IV}:
 Compounds 11,264
 Solid Solutions 11,263
- J
- Junction:
 Breakdown Due to Pipes, Diffused Si 11,485
 Positional Indicators of Radiation 11,515
- Junctions,
 Attaching Electrodes to 11,506
 Fabrication of Uniform Alloyed and Diffused
 11,488
 Formation of Boron-Doped Si 11,489
 Staining Etchant for Examination of Si 11,299
 Technique for Forming Alloyed p-n 11,500
- L
- L-Band:
 Amplifier, Tunnel Diode 11,551
 Masers, Cross-Relaxation in 11,524
 Parametric Amplifiers 11,548
- Lamination Stacks, Magnetic Cores with Interleaved
 11,519
- Laser:
 Beams, Physiological Effects of 11,587, 11,588
 Radiation, Theory of 11,526
- Lasers, Optical Pulses from 11,525
- Lanthanum Chromate,
 Electron PMR and Antiferromagnetism in 11,412
 Preparation and Crystal Structure of 11,412
- Lattice:
 Constant of:
 Ge-Si Alloys 11,337
 InP 11,292
 Constants:
 of Cubic Phase Solid Solutions in the AgSbSe₂-
 AgSbTe₂-AgBiSe₂-AgBiTe₂ System
 11,251
 in the HgSe-HgTe System, Effect of Annealing
 on the 11,357
 Faults, X-Ray Scattering Method for Studying
 11,260
 Parameters, Determination of 11,277, 11,278
 Vibrations, Frequency Spectra of 11,342
- Lattices,
 Analysis of Bond Structure in Wurtzite-Type
 11,279
 X-Ray and Slow Neutron Analysis of 11,247
- Lead Sulfide Films, Hall Mobilities of Epitaxial
 11,354
- Lead Telluride,
 Electrolytic Polishing of 11,324
 Mobility of Holes and Electrons in Solid Solutions
 Based on 11,356
- Leads,
 Electrodeposition of Molten Metals and Alloys
 on 11,326
 Pressure Dependence of Electrical Resistance of
 11,360
- Leg-Brace Force Tests, Electronic 11,586
- Lifetime:
 of Minority Carriers on Diode Characteristics,
 Effect of 11,486
 Tester 11,652
- Limiters 11,584
- Liquid Semiconductors, Properties of 11,332
- Lithium Fluoride,
 Charged Dislocations in 11,285
 Internal Friction of 11,476
 Optical Properties of 11,464
- Lithium Fluoride Whiskers, Growth of 11,300
- Logic:
 Devices, Fabrication of Magnetic 11,614
 Systems, Bibliography of All-Magnetic 11,612
- Low Frequency Instability in Cascaded Emitter Fol-
 lowers 11,553
- Low Power Transistor Amplifier 11,555
- Lucite, Recoilless Resonance Absorption Measurement
 of the Refractive Index of 11,461
- Luminescence:
 with Absorption Edge, Correlation of Edge
 11,450
 in GaP 11,449
 in Tunnel Diodes 11,480
 in Zn-Doped GaP 11,448
- Luminous Efficiencies of Phosphors at Low Excitation
 Current Densities 11,452
- M
- Machine:
 Tool, Digital Control of 11,624
 Tool Automation, Servo Systems for 11,625
- Magnesium-Germanium-Tin Compounds, Conduc-
 tivity of 11,377
- Magnesium-Manganese Ferrites, Advantages of
 Silica Additive in 11,521
- Magnesium Oxide, Charged Dislocations in 11,285
- Magnesium Tungstate, Growth of 11,321
- Magnetic:
 Amplifiers 11,556, 11,518
 Anisotropy:
 of Ferromagnetic Films, Torque Measurement
 of 11,405
 in Ni Films, Torque Measurement of 11,404
- Circuits 11,518
- Cores with Interleaved Lamination Stacks 11,519
- Field:
 Dependence of the Superconducting Penetra-
 tion Depth in Thin Films 11,384
 Electrodeposition of Ni-Fe Films 11,309
- Induction Meters 11,629
- Logic:
 Devices, Fabrication of 11,614
 Systems, Bibliography of 11,612
- Losses, Temperature Dependence of 11,403
- Materials Behavior at Nanosecond Pulse Widths
 11,520
- Moments,
 Ferromagnetic Garnets with High 11,319
 YIG with High 11,273
- Properties of:
 Co and Ni Films 11,399
 Co-Ni Platings 11,308
 Electrodeposited Ni-Fe Thin Films, Composi-
 tion and Thickness Effects on the 11,397
 Fe-Ni Electrodeposited Films 11,307
 $Mn_{0.75}Co_{0.05}Fe_{1.2}O_4$ 11,416
- Recording, Phase Equalization in 11,609
- Recording Layers, Preparation of Low Noise
 11,304
- Resonance Technique for Studying Energy Trans-
 fer in a Nuclear Spin System,
 Double 11,424

SUBJECT INDEX (Continued)

- Susceptibility of:
 A^{II}B^{VI} Compounds 11,272
 MnHg 11,411
- Switching:
 Circuits, Fabrication of 11,614
 System 11,564
- Tape Head, Playback Process of 11,610
- Magnetization,
 Calculations of Spontaneous 11,400
- Magnetization of:
 Antiferromagnets, Sublattice 11,410
 CrBr₃, NMR Determination of Temperature Dependence of the 11,401
 Nickel Particles, Effect of Chemisorbed Hydrogen on the 11,398
- Tape, Theory of 11,608
- Magnetoresistance:
 of Ge, Temperature and Magnetic Field Dependence of the 11,389
 in HgSe, Angular Dependence of the 11,388
- Magnetostriction:
 Constant of Ni 11,406
 of Mn_{1.75}Co_{0.05}Fe_{1.2}O₄ 11,416
- Magnets, Ferrites for Permanent 11,316
- Magnon-Phonon Coupling in Antiferromagnets 11,410
- Magnons in Thin Ferromagnetic Films, Interaction of Phonons and 11,407
- Manganese Ferrites with High Permeability 11,522
- Manganese Fluoride, Absence of Antiferromagnetic Domains in 11,413
- Manganese Fluoride Antiferromagnetic, Resonance Shift in 11,414
- Manganese Iron Ferrites, Magnetic Properties of 11,416
- Manganese Mercuride,
 Crystal Structure of 11,411
 Magnetic Susceptibility, Resistivity and Crystal Structure of 11,411
- Manganese-Zinc:
 Ferrites, Preparation of 11,313
 Ferrites with Temperature Independent Permeability, Preparation of 11,314
- Maser:
 Amplifier, Microwave 11,527
 Radiation,
 Giant Pulses of Optical 11,525
 Theory of Optical 11,526
- Masers,
 Cross-Relaxation Effects in 11,524
 Noise in Microwave 11,606
 Thermodynamics and Statistical Mechanics of Three-Level 11,523
- Masers in Optical-Band Radio Communication, Employment of 11,607
- Masking Techniques in Diffusion 11,504, 11,505
- Measurement of:
 Hall Mobilities by Rotating Sample Techniques 11,355
 Magnetic Anisotropy of Ferromagnetic Films, Torque Method of 11,405
 Phase with Transistor Flip-Flops 11,628
 Resistivity, Mutual Inductance Method for the 11,358
 Stress in Thin Electrodeposits 11,471
- Mechanical Properties of Crystals, Effect of Dislocations on 11,284
- Medical Electronics:
 Brain Potential Measurement Device 11,585
- Laser:
 Beam Effects 11,587
 Produced Optical Lesions 11,588
 Leg-Brace Tests 11,586
- Mercuric Selenide, Crystal Structure and Preparation of 11,357
- Mercuric Selenide-Mercuric Telluride, Preparation of Solid Solutions of 11,357
- Mercuric Selenide-Mercuric Telluride System, Effect of Annealing on the Lattice Constants in the 11,357
- Mercuric Telluride, Crystal Structure and Preparation of 11,357
- Mercury Selenide, Magnetoresistance of 11,388
- Mercury Selenide:
 with HgS, Solubility and Magnetic Susceptibility of 11,272
 Infrared Detectors, Fabrication and Properties of 11,513
- Mercury Telluride:
 as a Function of Pressure, Resistivity of 11,361
 with HgSe or HgS, Solubility and Magnetic Susceptibility of 11,272
- Mercury Tellurides, Properties of HgTe-HgSe; HgTe-HgS; HgSe-HgS 11,373
- Metal Films, Structure of Noble 11,295
- Metallic Solid Solutions, Structure of 11,260
- Meteorological Infrared Radiometer 11,630
- Microhardness Analysis of Zincblende Structure Alloys 11,474
- Microwave:
 Receivers, Noise in 11,606
 and UHF Systems, Ferrite Components for 11,605
- Miniaturization Techniques 11,530, 11,531, 11,532, 11,533, 11,534, 11,535
- Miniaturized Packages for Junction Transistors 11,508
- Missile Arming-Fuzing Timer 11,594
- Mixer, Tunnel Diode 11,571
- Mobilities, Measurement of Hall 11,355
- Mobilities of:
 A₂IVB₂VI Compounds, Hole and Electron 11,356
 A₂V₂B₂VI Compounds, Hole and Electron 11,356
 CdSb 11,436
 Epitaxial PbS Films, Hall 11,354
 HgSe, HgTe, and Solid Solutions of HgSe and HgTe 11,357
 In(As_{1-x}P_{1-y}) 11,396
 Warm Electrons in Cubic Semiconductors, Field Dependence of the 11,353
- Modulators, Ferrite 11,561
- Monitor, Signal Level 11,566
- Mosaic Structure in Ge and Si Single Crystals 11,287
- Motor Speed Regulator, Digital 11,623
- Multiplexer 11,603
- N
- Navigation System, Satellite 11,595
- Negative Resistance:
 of Avalanche Transistors 11,498
 Oscillators 11,559
 Oscillators, Tunnel Diode 11,558
- Networks,
 Design of Compensating 11,528
 Nonlinear: Graphic Analysis of 11,529
- Neutron:
 Dosimeter, Phosphate Glass 11,636
 Flux Distribution in Reactor Cores, Ge Dosimeter for Determining 11,641
 Scattering Analysis of Binary Alloys 11,247
- Neutron:
 -Gamma Dosimeter 11,640
 -Irradiated Fused Silica, Ultrasonic Attenuation Measurements in 11,475
- Neutrons by Means of Thermoluminescence, Dosimetry of 11,639
- Nickel,
 Effect of Pressure on Electroless Plating of 11,328
 Magnetostriction Constant of 11,406
- Nickel:
 Films,
 Preparation and Properties of Plated 11,399
 Torque Measurements of Magnetic Anisotropy and Hysteresis Loss in 11,404
 Particles, Effect of Chemisorbed Hydrogen on the Magnetization of 11,399
- Nickel-Cobalt Platings, Structure and Magnetic Properties of 11,308
- Nickel-Iron:
 Films, Preparation and Properties of Plated 11,309
 Thin Films, Composition and Thickness Effects on the Magnetic Properties of Electrodeposited 11,397
- Nickel-Zinc Ferrites with High Initial Permeabilities and Low Magnetic Losses, Preparation of 11,315
- Niobium, Pressure Dependence of Electrical Resistance of 11,360
- Niobium-Molybdenum Alloys, Superconductivity Transition Temperature of 11,386
- Noise:
 Figure of:
 Preamplifiers 11,537
 Tunnel Diode Amplifiers 11,538
 Level Reduction of Magnetic Tape Powders 11,304
 in Microwave Receivers 11,606
 Performance, Interpretation of Transistor 11,539
- Noncrystalline Semiconductors, Properties of 11,332
- Nonlinear Circuit Analysis, Graphic 11,529
- Nonsaturating Pulse Amplifier 11,543
- Nuclear:
 Magnetic Resonance:
 in Bloch Walls 11,425
 of Cr³⁺ in CrBr₃ 11,401
 Detection of the Guanidium Ion in GASH 11,347
 Determination of Temperature Dependence of the Magnetization of CrBr₃ 11,401
 Pulse Experiments, Nuclear Transfer Effects in 11,426
 of Sn¹¹⁹ in Sn 11,427
 Relaxation Rates of Antiferromagnets 11,410
 Specific Heat of Ho 11,466
- Spin:
 System, Double Magnetic Resonance Technique for Studying Energy Transfer in 11,424
 System in:
 Al, Al²⁷ 11,424
 CaSO₄ · 2H₂O, Proton 11,424
 Transfer Effects in Nuclear Magnetic Resonance Pulse Experiments 11,426
- Nucleation of Thin Films, Methods for Study of 11,293
- O
- Ocular Lesions Produced by an Optical Maser (Laser) 11,588
- Optical:
 Absorption:
 in CdS, Effect of Metallic Impurities on 11,439
 of Electron Excess Centers in KCl 11,421
- Maser Radiation,
 Giant Pulses of 11,525
 Theory of 11,526
- Properties of:
 Bi₂Se₃-Bi₂Te₃ Alloys 11,336
 Ge-Si Alloys 11,337
 Y₂O₃ 11,438
 Saturation of F-Center Spin Resonance 11,440
 Optical-Band Radio Communication 11,607
- Order-Disorder Transition in the AgSbSe₂-AgSbTe₂-AgBiSe₂-AgBiTe₂ System 11,251
- Organic Compounds, Dark Conductivity in 11,456
- Oscillator Modules 11,658
- Oscillators,
 Blocking 11,560
 Square Wave 11,577
 Synchronized 11,559
 Triggered 11,559
 Tunnel Diode: 11,557
 Crystal-Controlled 11,558

SUBJECT INDEX (Continued)

Oxide Films on Semiconductor Surfaces, Measurements of Thickness and Refractive 11,322

P

Packages for Junction Transistors, Miniaturized 11,508

Packaging:
Methods Employing Dot Components 11,532
of Rectifiers 11,492
of Semiconductor Devices 11,507

Palladium, Epitaxial Growth and Twinning in 11,295

Paramagnetic:

Relaxation in Anisotropic Crystals 11,418

Resonance of:

Ce^{3+} and Er^{3+} in $CaWO_4$, Spectral Diffusion in the 11,428

Cr^{3+} in YGa and YAl Garnets 11,419

Deformed InSb, Ge and Si 11,420

Electron Excess Carriers in KCl 11,421

Fe^{57} in CoO, Hyperfine Structure of 11,417
an Irradiated Single Crystal of Urea Oxalate 11,422

LaCrO₃ 11,412

X-Irradiated Single Crystals of Rochelle Salt 11,423

Susceptibility of $Gd_5Fe_5O_{12}$ 11,402

Tungstates, Growth of 11,321

Parametric:

Amplifiers 11,549

Amplifiers,

L-Band Traveling Wave 11,548

Low Frequency Pump 11,546

Parity Check Switching Circuit 11,613

Peltier Coolers, Transient Effects in 11,516

Penetration Depth in Thin Films, Magnetic Field Dependence of the Superconducting 11,384

Permalloy Alloys for Switching Applications 11,317

Permeabilities and Low Magnetic Losses, Preparation of Ferrites with High Initial 11,315

Permeability of:

Cores, Effective Pulse 11,520

Mn Ferrites 11,522

Mn-Zn Ferrites, Temperature-Independent 11,314

Phase:

Diagram of:

InAs-Sb 11,250

the System InAs-InAs-InSb 11,249, 11,250

Diagrams, Review of Semiconductor 11,246

Diagrams of:

Binary Alloys 11,248

Ternary III-V Compounds 11,257

Equalization in Magnetic Recording 11,609

Meter Employing Transistor Flip-Flops 11,628

Transition of In_2Se_3 11,276

Phases of Na, Low Temperature 11,467

Phonon-Magnon Coupling in Antiferromagnets 11,410

Phonons, Excitation of Spin-Wave Resonance by Microwave 11,407

Phosphor:

Scintillators 11,634

Screens, Luminescence Efficiency of ZnS:Ag 11,452

Phosphors, Effect of:

Infrared Irradiation on ZnS:Cu 11,443

Temperature and Pressure on the Absorption Spectra of Four Alkali Halide 11,430

Phosphorus in Si, Open Tube Diffusion of 11,291

Phosphorus-Cobalt Films, Preparation and Properties of Plated 11,306

Photocells, Grain Boundary 11,429

Photoconductivity of:

AII₂VI - A₃III₂VI Compounds 11,457

Alloys of the Sulfides of Thallium, Antimony and Bismuth 11,375

Binary III-VI Alloys 11,457

CdS 11,455

CdTe-ZnTe Compounds 11,376

Group V-VI-VII Compounds 11,458

Se Layers 11,454

Semiconductors, Influence of Traps on 11,453

Tl₂Sb₂Se₄ 11,374

Photoeffect in Metal-Semiconductor Contacts 11,460

Photoelectric Effects in CdS 11,512

Photoluminescence in Zn-Doped GaP 11,448

Photovoltaic Effect in a Radiation Position Indicator, Application of 11,515

Physical:

Properties, Review of Semiconductor 11,246

Properties of:

KCl-KBr 11,366

Semiconductors 11,331

Physiological Effects of Laser Beams 11,587

Piezoelectric Properties of ZnO 11,318

Pipes, Breakdown in Diffused Si Junctions Due to 11,485

Planar Diffusion Techniques 11,504

Plastic Deformation on Magnetostriction Constant of Ni, Effect of 11,406

Plating of Ni, Effect of Pressure on Electroless 11,328

Playback Process of a Magnetic Ring Head 11,610

Polishing:

Cloth 11,650

of PbTe, Electrolytic 11,324

Polyethylene, Dielectric Properties of Irradiated Dielectric 11,344

Potassium Chloride, Optical Absorption and ESR of Electron Excess Centers in 11,421

Potassium Chloride-Potassium Bromide, Physical and Thermodynamic Properties of 11,366

Potassium Cobalt Fluoride, Electron Distribution in 11,343

Potassium Iron Fluoride, Electron Distribution in 11,343

Potassium Manganese Fluoride, Electron Distribution in 11,343

Potassium Nickel Fluoride, Electron Distribution in 11,343

Powders, Preparation of Low Noise Magnetic 11,304

Power:

Amplifier, Linear 11,554

Diodes, Measurement of Thermal Parameters of 11,487

Generators, UHF 11,573

Supplies, dc 11,619

Supply for Telephone Carrier Equipment 11,600

Switching 11,619

Preamplifiers,

Noise Figure of 11,537

Transistorized Small Current 11,555

Precious Metals for Semiconductor Device Fabrication Clad Materials 11,647

Preparation of:

Ferromagnetic Garnets 11,319

InP 11,292

Low Magnetic Moment $Y_3AlFe_4O_{12}$ Garnets 11,303

Pressure, Resistivity of HgTe as a Function of 11,361

Pressure on Ge, Effects of 11,362

Programmed Superconductor Ring Commutator 11,615

Pulse:

Amplifier 11,575

Amplifier, Nonsaturating 11,543

Code Modulation Encoder 11,602

Delay Circuits 11,579

Generators 11,559

Generators,

Avalanche Transistor 11,498

p-n-p-n 11,574

Regenerative 11,575

Height Analyzer 11,580

Selector for Airborne Distance Measuring Equipment 11,590

Stretcher, Zero Suppressed 11,582

Width Shaper 11,581

Purification of B by Floating Zone Method 11,301

Q

Quantum Flux in a Superconducting Tube 11,381

R

Radar:

Boxcar Circuits 11,568

Tranceiver Amplifier 11,549

Radiation, Production of Divacancies in Si by Electron 11,281

Radiation:

Detectors, Development of Gamma- and X- 11,514

by Means of Thermoluminescence, Dosimetry of Ionizing 11,639

Position Indicator Employing Lateral Photovoltaic Effect 11,515

Radiometer, Infrared 11,630

Rare Earth:

Ethyl Sulfate, Paramagnetic Relaxation in 11,418

Iron Garnets, Preparation:

of High Resistivity 11,320

and Properties of 11,319

Iron Garnets with High Magnetic Moments, Solid Solutions of 11,273

Reactor Cores, Ge Dosimeter for Determining Neutron Flux Distribution in 11,641

Receiver for Distance Measuring Equipment System, Airborne 11,591

Receivers,

Antenna Circuits for 11,597

Radio: Miniaturized 11,659

Recombination:

of Carriers in Semiconductors 11,350

Centers, Density and Energy Levels of Surface 11,392

Centers in Ge, Surface 11,351

of Interstitials with Vacancies in Cu 11,282

Recording Layers, Preparation of Low Noise Magnetic 11,304

Rectifier, Controlled: Si Diffused 11,655

Rectifier Test Set 11,656

Rectifiers, Fabrication and Packaging of 11,492

Reflection:

Spectra of Ge-Si Alloys 11,334

Spectrum in LiF 11,464

Refractive Index of Lucite by Recoilless Resonance Absorption, Measurement of the 11,461

Regenerative Pulse Amplifier 11,575

Regulation of Power Supplies, dc 11,619

Relaxation:

Effects in Ruby Masers, Cross- 11,524

Oscillators 11,559

Time in YIG, Ferromagnetic Spin Lattice 11,408

Relays, Static 11,626

Resistance of:

Granular Carbon Aggregates, Effect of Heat Treatment on the Electrical 11,365

Pressure Dependence of Metals 11,360

Resistivity, Mutual Inductance Method for the Measurement of 11,358

Resistivity:

in Au Wires, Annealing of Quenched-in Extra 11,364

of Cubic Sodium Tungsten Bronze 11,378

as a Function of Pressure 11,361

SUBJECT INDEX (Continued)

- of GaAs 11,372
 - GaAs, Energy Level Model for High 11,340
 - of Ge-Si Alloys 11,369
 - of MnHg 11,411
 - of Te and Te-Se Alloys 11,370
 - Resistors, Characteristics of Thin Film 11,477
 - Resonance:
 - Absorption, Measurement of the Refractive Index of Lucite by Recoilless 11,461
 - Shift in Antiferromagnetic MnF_2 11,414
 - Reverse Characteristics of Ge Junction Diodes 11,484
 - Rhenium, Pressure Dependence of Electrical Resistance of 11,360
 - Ring, Superconductor: Programmed 11,615
 - Rochelle Salt, Paramagnetic Resonance of X-Irradiated 11,423
 - Rocksalt, Charged Dislocations in Pure and Doped 11,285
- S
- Saccharin as Additive in Ni-Co Plating Bath 11,308
 - Sampling Switches 11,568
 - Satellite Instrumentation, Project Transit 11,595
 - Sawtooth Generators 11,559, 11,576
 - Scattering Mechanisms, Dependence of Faraday Ellipticity in Semiconductors on 11,463
 - Scintillation Counters,
 - Cerium-Activated Glasses for 11,633
 - Phosphors for 11,634
 - Selenium, Lattice Constant of 11,277
 - Selenium Layers, Photoconductivity of 11,454
 - Semiconductor:
 - Alloys,
 - Effects of Disorder on the Physical Properties of 11,331
 - Review of 11,246
 - Contacts, Photoeffect in 11,460
 - Surface Phenomena, Field Effect Studies of 11,392
 - Surfaces, Attaching Electrodes 11,506
 - Semiconductors,
 - Determination of Impurities in 11,288
 - Field Dependence of the Mobility of Warm Electrons in Cubic 11,353
 - Influence of Traps on Photoconductivity in 11,453
 - Noncrystalline, Amorphous and Liquid 11,332
 - Semiconductors on Scattering Mechanism, Dependence of Faraday Ellipticity in 11,463
 - Shearing of Initial Permeability for Magnetic Core with Interleaved Lamination Stacks 11,519
 - Shift Registers, Tunnel Diode-Transistor 11,611
 - Silica, Ultrasonic Attenuation Measurements in Neutron-Irradiated Fused 11,475
 - Silica Additive in Mg-Mn Ferrites, Advantages of 11,521
 - Silicon,
 - Field Dependence of the Mobility of Warm Electrons in 11,353
 - Impurity Gettering during Diffusion in 11,289
 - Open Tube Diffusion of P in 11,291
 - Resonance in Deformed 11,420
 - Silicon:
 - Crystals by Floating Zone, Solid-Liquid Interface during Growth of 11,299
 - by Electron Irradiation, Production of Divacancies in 11,281
 - Single Crystals, Mosaic Structure in 11,287
 - Surfaces, Melting Point Depression of Impure 11,274
 - Silicon-Germanium System, Analysis of 11,254
 - Silver, Epitaxial Growth and Twinning in 11,295
 - Sliding Effect in Bi, Anomalous 11,395
 - Sodium,
 - Low Temperature Phases of 11,467
 - Specific Heat of 11,467
 - Sodium Chloride,
 - Effect of the Precipitation of Dissolved $MnCl_2$ on the Low Temperature Thermal Conductivity of 11,469
 - Internal Friction of 11,476
 - Sodium Chloride Crystals with Pb Impurity, Conductivity of 11,363
 - Sodium Tungsten Bronze, Resistivity of 11,378
 - Solid:
 - Solubility of In_2Se_3 in Zincblende Structure Compounds 11,271
 - Solutions,
 - High Magnetic Moments in Garnet 11,273
 - Review of Semiconductor 11,246
 - Structure of Metallic 11,260
 - Solutions:
 - of $AlIBVI$ 11,261, 11,272
 - of $AlIBVI-A_2III_BVI$ 11,262
 - of $AlIBV$ 11,263, 11,264, 11,265
 - in $AlSb-Al_2Te_3$ System 11,269
 - in the $AlSb-GaSb$ System 11,268
 - of the Arsenoselenides of Ga, Formation and Analysis of 11,266
 - of $Ga_2Te_3-In_2Te_3$ 11,267
 - of $InAs-In_2Te_3$ 11,270
 - of YIG and Rare Earth Iron Garnets 11,319
 - Solubility of:
 - Al in Ge 11,254
 - Sn in Ge 11,254
 - Soret Effect 11,470
 - Space Systems, Critical Engineering 11,596
 - Specific Heat of:
 - $Cr_{80.6}Fe_{19.4}$ 11,468
 - Ge 11,465
 - Ho, Nuclear Contribution to the 11,466
 - Na 11,467
 - Spectrochemical Determination of Impurities in Semiconductors 11,288
 - Spectrogoniometer, Determination of Lattice Parameters by 11,277
 - Spectrophotometer, CdS 11,455
 - Spectrum of Ammonia in Solid Argon at 4.2°K, Ultraviolet Absorption 11,441
 - Speed Regulator, Motor 11,623
 - Spin:
 - Lattice Relaxation Time in YIG, Ferromagnetic 11,408
 - Resonance, Optical Saturation of F-Center 11,440
 - Spin-Wave Resonance by Microwave Phonons, Excitation of 11,407
 - Square Wave Generators 11,577
 - Stark Exciton Effect in Cu_2O 11,431
 - Steering Circuits, HF 11,569
 - Stitched-Wiring Process for Miniaturized Communications Electronics 11,531
 - Storage:
 - in Switching Transistors 11,494
 - Units, Parametric 11,546
 - Strain Gauge Applications in Medical Electronics 11,586
 - Stress in Thin Electrodeposits, Measurement of 11,471
 - Strontium Fluoride, Discoloration Spectra of 11,433
 - Strontium Titanate, Infrared Transmittance of 11,435
 - Strontium Tungstate, Growth of 11,321
 - Structural Properties of Fe-Ni Films 11,307
 - Structure of:
 - Alloys of the Sulfides of Thallium, Antimony and Bismuth 11,375
 - In_2Se_3 and In_2Te_3 11,296
 - Superconducting:
 - Films, Transition Temperatures of 11,383
 - Penetration Depth in Thin Films, Magnetic Field Dependence of the 11,384
 - Tin, Transition Temperature of Thin Films of 11,385
 - Tube, Quantum Flux in a 11,381
 - Superconductivity, Bardeen-Cooper-Schrieffer Theory of 11,379, 11,380
 - Superconductivity:
 - in Thin Films 11,382
 - Transition Temperature of Nb-Mo Alloys 11,386
 - Superconductor Ring Commutator, Programmed 11,615
 - Surface:
 - Contacts to Si, Formation of 11,489
 - Phenomena, Field Effect Studies of Semiconductor 11,392
 - Protection by Coating, Study of 11,477
 - Recombination, Effect of Humidity on 11,352
 - Recombination Centers in Ge 11,351
 - Resistance Measurements in Bismuth 11,395
 - Surfaces,
 - Attaching Electrodes to 11,506
 - Damaged Layer in Abraded Ge 11,323
 - Measurements of Thickness and Refractive Index of Oxide Films on Semiconductor 11,322
 - Melting Point Depression of Impure Si 11,274
 - Susceptibility, Calculations of Reduced Magnetic 11,400
 - Susceptibility of:
 - Antiferromagnets, Parallel 11,410
 - $Gd_2Fe_2O_{12}$, Paramagnetic 11,402
 - Sweep Generator 11,576
 - Switching:
 - Applications, Permalloy Alloys for 11,317
 - Circuits,
 - Bistable High-Speed 11,562
 - Fabrication of 11,614
 - Flip-Flop Tunnel Diode 11,563
 - High Current HF 11,569
 - High-Speed Ferrite 11,561
 - Parity Check 11,613
 - Transistor-Magnetic Core 11,564
 - Devices, Low Magnetic Moment Garnets for Use in 11,303
 - Systems 11,626
 - Systems,
 - Telegraphic 11,601
 - Telephone and Telegraph 11,599
 - Transistors,
 - Design of 11,494
 - Design and Properties of Ge Ultra High-Speed 11,495
 - Si Alloyed 11,657
- T
- Tantalum, Thermionic Emission from 11,394
 - Tape Magnetization, Theory of 11,608
 - Telegraph Switching Systems 11,599, 11,601
 - Telemetry, Multiplexer for 11,603
 - Telemetry System, Digital Data 11,604
 - Telephone Switching Systems 11,599
 - Television Converter, dc 11,598
 - Tellurium,
 - Energy Band Structure of 11,391
 - Galvanomagnetic Coefficients of 11,391
 - Resistivity and Hall Coefficient of 11,370
 - Tellurium-Selenium Alloys,
 - Energy Gap in 11,370
 - Resistivity and Hall Coefficient of 11,370
 - Ternary:
 - Alloys,
 - Review of Semiconductor 11,246
 - X-Ray and Slow Neutron Analysis of 11,247
 - Systems, Rate of Contact Melting in 11,275
 - Tertiary Systems, Rate of Contact Melting in 11,275
 - Textural Properties of Ge Films 11,294
 - Thallium-Antimony-Selenium Ternaries, Properties and Structure of 11,374
 - Thallium Sulfide-Antimony Sulfide System, Photoconductivity and Structure of Alloys in the 11,375
 - Thermal:
 - Conductivity of:
 - Ga_2Te_3 and In_2Te_3 11,371

SUBJECT INDEX (Continued)

NaCl, Effect of the Precipitation of Dissolved MnCl_2 on the Low Temperature 11,469

Design in High Density Electronic Packaging 11,535

Detectors, Forced Cycled Cooling of 11,517

EMF of:

- GaAs 11,372
- GaAs, Temperature Dependence of 11,359

Parameters of Power Diodes, Measurement of 11,487

Properties of:

- Dielectrics 11,345
- Transistors, Measurements of 11,499

Thermionic Emission:

- from Tantalum 11,394
- of UC-Nb 11,393

Thermocouples, Advancing Network for 11,631

Thermoelectricity in Fluids: Soret Effect 11,470

Thermodynamic Properties of KCl-KBr Solid Solutions 11,366

Thermoelectric:

- Coolers, Transient Effects in 11,516
- Power Meter 11,653
- Powers of Solid Solutions in the AgSbSe_2 - AgSbTe_2 System 11,251

Thermoelectromotive Force of AlIIBVI Compounds 11,373

Thermoluminescence, Dosimetry of Ionizing Radiation and Neutrons by 11,639

Thermoluminescent Gamma-Ray Dosimeter 11,638

Thermometers, Characteristics of Thin Film 11,477

Thermostimulated Current Curves of Irradiated CdS 11,367

Thin Base Diodes, Effect of Deep Impurities on the I-V Characteristics of 11,481

Thin Film:

- Microcircuits 11,534
- Resistors and Thermometers, Characteristics of 11,477
- Techniques 11,530
- Technology, Survey of 11,533

Thin Films, Nucleation of NiFe, Au 11,293

Timer, Arming-Fuzing: Atomic Artillery Missile for 11,594

Timers 11,643

Timing Chains, Impulse 11,579

Tin,

- Nuclear Magnetic Resonance of Sn^{119} in 11,427
- Pressure Dependence of Electrical Resistance of 11,360
- Transition Temperature of Thin Films of Superconducting 11,385

Torque in Anisotropic Permalloy Films, Angular Dependence of 11,404

Transfluxors as Integrating Magnetic Amplifiers 11,544

Transform Generator, Fourier 11,578

Transistor:

- Noise Performance, Interpretation of 11,539
- Thermal Properties, Measurement of 11,499

Transistors,

- Design:

 - and Properties of Ge Ultra High-Speed Switching 11,495
 - of Switching 11,494

- Field-Effect:

 - Fabrication of 11,511
 - High Frequency 11,510

- Junction:

 - Characteristics of High Frequency 11,493

Electrodeposition of Solder on Leads for 11,326

Fabrication of:

- Diffused Drift 11,497
- Epitaxial 11,501
- High Frequency 11,502
- High Current Gain 11,503
- High Frequency Drift 11,496
- Miniaturized Packages for 11,508
- Theory and Applications of Avalanche 11,498
- Masking Techniques for Diffused 11,504, 11,505
- Metallic Desiccants for Use in 11,509

Transition Temperatures of Superconducting:

- Films 11,383
- Nb-Mo Alloys 11,386
- Tin-on-Gold Films 11,385

Transmittance of:

- SrTiO_3 , Infrared 11,435
- Y_2O_3 , Infrared 11,438

Traps in:

- CdS, Electron and Hole 11,367
- Semiconductors, Theory of 11,453

Traveling Wave Parametric Amplifiers 11,548

Tunnel Diode:

- Amplifiers,

 - Coupling in 11,552
 - Noise Figure of 11,538

- Characteristic Curve, Derivation of 11,478
- Crystal Oscillator 11,558
- Down Converter 11,571
- Equivalent Circuit 11,550
- Flip-Flop 11,563
- HF Amplifiers 11,550
- L-Band Amplifier 11,551
- Module Two Adder 11,617
- Oscillators 11,557

Tunnel Diodes,

- Frequency Limitations of 11,479
- Infrared Luminescence in 11,480

Twinning in Noble Metal Films Evaporated on LiF and Mica 11,295

U

Ultra High Frequency:

- and Microwave Systems, Ferrite Components for 11,605
- Power Generators 11,573

Ultrasonic Attenuation Measurements in Neutron-Irradiated Fused Silica 11,475

Ultraviolet:

- Absorption:

 - in CdS 11,442
 - Spectrum of Ammonia in Solid Argon at 4.2°K 11,441

- Radiation, Enhancement of Electroluminescence in ZnS:Cu , Al Phosphors by 11,444

Uranium Carbide-Niobium, Thermionic Emission of 11,393

Urea Oxalate, Electron Spin Resonance of 11,422

V

Vacancies in Cu, Recombination of Interstitials with 11,282

Vacuum Evaporator 11,649

Video Amplifier Module, Transistor 11,542

Viscosity of $\text{Mn}_{1.75}\text{Co}_{0.05}\text{Fe}_{1.2}\text{O}_4$ Magnetic 11,416

Voltage:

- Breakdown in Diffused Si Junctions Due to Pipes 11,485

to Frequency Converters 11,570

Regulators,

- Transistor 11,620
- Zener Diode 11,621

W

Wein Bridge Frequency Meter 11,627

Whiskers, Growth of LiF 11,300

Wood's Alloy, Pressure Dependence of Electrical Resistance of 11,360

Wurtzite:

- Lattice, Elastic Properties of 11,472, 11,473
- Lattice of Annealed $\text{A}_2\text{IIIIB}_3\text{VI}$ Alloys 11,297

Wurtzite-Type Lattices, Analysis of Bond Structure in 11,279

X

X-Radiation Detectors, Development of 11,514

X-Ray:

- Analysis of $\text{AIII BV} - \text{AIII BVI}$ and $\text{AIII BV} - \text{A}_2\text{III B}_3\text{VI}$ Compounds 11,255

Scattering:

- Analysis of Binary Alloys 11,247
- Method for Studying Lattice Faults 11,260

Y

Yttrium, Pressure Dependence of Electrical Resistance of 11,360

Yttrium Aluminum Garnets, Paramagnetic Resonance of Cr^{3+} in 11,419

Yttrium Aluminum Iron Garnets, Preparation of Low Magnetic Moment 11,303

Yttrium Gallium Garnets, Paramagnetic Resonance of Cr^{3+} in 11,419

Yttrium Iron Garnet,

- Ferromagnetic Spin Lattice Relaxation Time in 11,408
- Preparation:

 - of High Resistivity 11,320
 - and Properties of 11,319

Yttrium Iron Garnet:

- with High Magnetic Moments, Solid Solutions of 11,273
- Large Single Crystals, Growth of 11,318

Yttrium Oxide, Optical Properties of 11,438

Z

Zinc Oxide, Piezoelectric Properties of 11,318

Zinc Sulfide,

- Electroluminescence of 11,445
- Electroluminescence in Cu and Mn Activated 11,446

Zinc Sulfide:

- Phosphors, Effect of Infrared Irradiation on 11,443
- Phosphors by Ultraviolet Radiation, Enhancement of Electroluminescence in 11,444

Zinc Tungstate, Growth of 11,321

Zincblende:

- Lattice, Elastic Properties of the 11,473
- Lattice of $\text{A}_2\text{III B}_3\text{VI}$ Alloys 11,297
- Structure Alloys, Microhardness Analysis of 11,474

Zirconium, Pressure Dependence of Electrical Resistance of 11,360

Zone Melting, Preparation of B by Floating 11,301

AUTHOR INDEX

- Abel, K. 11, 547
 Abraham, A. 11, 334
 Abrams, Jr., R.H. 11, 393
 Adams, E.N. 11, 387
 Adler, E. 11, 498
 Airapetiants, S.V. 11, 356
 Albers-Schoenberg, E. 11, 521
 Aleksandrowicz, J. 11, 641
 Amemiya, H. 11, 528
 Arai, T. 11, 516
 Arend, H. 11, 432
 Aronov, D.A. 11, 486
 Aronson, R. 11, 587
 Asdente, M. 11, 341
 Attix, F.H. 11, 635
 Aulmann, A. 11, 601
 Austin, I.G. 11, 336
 Auxier, J.A. 11, 637
 Bach, L.M.N. 11, 585
 Baird, S.S. 11, 483
 Baker, Jr., G.A. 11, 400
 Balchan, A.S. 11, 430
 Ballentyne, D.W.G. 11, 444
 Bardeen, J. 11, 381
 Barker, W.A. 11, 523
 Bartenbach, M. 11, 641
 Bederke, H.J. 11, 619
 Beijinink, W. 11, 600
 Belser, R.B. 11, 477
 Benjamin, C.E. 11, 322
 Bennion, D.R. 11, 612
 Benson, K.E. 11, 251
 Bernard, C.H. 11, 637
 Bir, G.L. 11, 420
 Blair, J. 11, 361
 Blanc, J. 11, 340
 Blanks, L. 11, 514
 Blaughner, R.D. 11, 386
 Bloembergen, N. 11, 414
 Blue, M.D. 11, 513
 Bockmuehl, R.R. 11, 512
 Boer, K.W. 11, 345
 Bogle, G.S. 11, 524
 Bogorodskii, O.V. 11, 287
 Bol'shova, K.M. 11, 416
 Bond, W.L. 11, 451
 Booker, G.R. 11, 322
 Borshchevskii, A.S. 11, 474
 Boswell, D. 11, 492
 Bozorth, R.M. 11, 402
 Bradley, W.E. 11, 567
 Brady, L.J. 11, 522
 Braun, J.H. 11, 299
 Breinin, G.M. 11, 588
 Brenner, R. 11, 519
 Brezina, B. 11, 348
 Bridges, J.M. 11, 596
 Briggs, G.A. 11, 367
 Brigrmanis, E. 11, 517
 Brodwin, M.E. 11, 463
 Brooks, H. 11, 362
 Brudiyan, I.I. 11, 268
 Bryant, C.A. 11, 465
 Brysneva, L.A. 11, 279
 Buckley, S.E. 11, 311
 Busch, G. 11, 377
 Cacheris, J.C. 11, 605
 Cahill, A.E. 11, 293
 Calgagno, L. 11, 539
 Calhoun, B.A. 11, 303
 Cambell, D.S. 11, 530
 Carey, Jr., W.N. 11, 569
 Carr, J.M. 11, 306
 Carson, J.W. 11, 419
 Cattaneo, F. 11, 364
 Cely, J. 11, 342
 Chambers, R.G. 11, 358
 Chang, C.M. 11, 495
 Chang, K.K.N. 11, 571
 Chappay, M.A. 11, 511
 Cheng, C.H. 11, 468
 Christensen, S.H. 11, 421
 Christian, S.M. 11, 337
 Clapper, G.L. 11, 562
 Clayton, C.G. 11, 367
 Clemson, D. 11, 309
 Clifton, J.K. 11, 501
 Coffin, J.M. 11, 531
 Constantakes, P. 11, 504
 Cooper, T.W. 11, 506
 Copeland, J.R. 11, 597
 Corbett, J.W. 11, 281
 Corneretto, A. 11, 604
 Coufova, P. 11, 432
 Crane, H.D. 11, 612
 Damaskova, S. 11, 446
 Dandl, R.A. 11, 555
 Danielson, G.C. 11, 378
 Davey, J.E. 11, 294
 Davies, L.W. 11, 515
 Decker, R.O. 11, 518
 Deichen, J.H. 11, 620
 Dekeyser, W. 11, 285
 DeLotto, I. 11, 581
 Dempsey, C.W. 11, 466
 Dickens, L.E. 11, 538
 Dienes, G.J. 11, 283
 Diesel, T.J. 11, 389
 Dietz, R.E. 11, 398
 Dorda, G. 11, 352
 Douglass, Jr., D.H. 11, 384
 Doyle, W.D. 11, 404
 Dressler, K. 11, 441
 Drickamer, H.G. 11, 430
 Drivov, M.A. 11, 372
 Dumin, D.J. 11, 615
 Duncan, J.F. 11, 455
 Duwez, P. 11, 259
 Eberhard, E. 11, 559
 Eddy, D.S. 11, 512
 Efimova, B.A. 11, 356
 Eichbaum, B.R. 11, 312
 Elkina, T.A. 11, 416
 Elpat'evskaja, O.D. 11, 357
 Emeis, R. 11, 489
 Emerson, W.A. 11, 298
 Engelbart, D.C. 11, 612
 Ermanis, F. 11, 436
 Evans, J.A. 11, 335
 Ewels, J. 11, 492
 Fan, G.J. 11, 610
 Faust, Jr., J.W. 11, 488
 Federova, N.A. 11, 261
 Fedorova, N.N. 11, 263
 Feiner, A. 11, 543
 Feldman, D.W. 11, 440
 Fiks, V.B. 11, 470
 Finn, M.C. 11, 325
 Fisher, R.D. 11, 399
 Flint, P.S. 11, 485
 Flowerday, T.W. 11, 557
 Folberth, O.G. 11, 338
 Foot, R.S. 11, 611
 Fousek, J. 11, 348
 Foyt, A.G. 11, 493
 Frait, Z. 11, 409
 Francis, G.W. 11, 452
 Francis, S. 11, 535
 Frank, R.C. 11, 532
 Frank-Kamennetskii, V.A. 11, 262
 Franklin, D.P. 11, 583
 Freshour, S. 11, 560
 Friedel, J. 11, 341
 Fullbright, H.J. 11, 514
 Fuller, C.R. 11, 483
 Fuller, D.Q. 11, 496
 Furdyna, J.K. 11, 463
 Gadsden, C.P. 11, 585
 Galkina, T.I. 11, 351
 Gardner, F.F. 11, 524
 Garfunkel, J.H. 11, 513
 Garrett, C.G.B. 11, 451
 Gatos, H.C. 11, 325
 Geballe, T.H. 11, 386
 Geddes, W.K.E. 11, 578
 Geller, S. 11, 251
 Gels, J. 11, 273
 Germagnoli, E. 11, 364
 Gershenson, M. 11, 482
 Giger, G.A. 11, 634
 Gile, W.W. 11, 566
 Gillett, C.M. 11, 335
 Ginther, R. 11, 633
 Glickman, M.N. 11, 508
 Glicksman, M. 11, 331
 Gniwew, J.J. 11, 403
 Godycki, L.E. 11, 307
 Gold, A. 11, 434
 Gold, L. 11, 462
 Goldberg, J.L. 11, 616
 Goldberg, P. 11, 447
 Golik, L.L. 11, 442
 Goodman, C.H.L. 11, 274
 Goodwin, F.E. 11, 527
 Goodykoontz, J.R. 11, 532
 Gordon, J.E. 11, 466
 Gordy, W. 11, 422
 Gornyi, N.B. 11, 330
 Goryunova, N.A. 11, 261
 Gold, L. 11, 261
 Gold, L. 11, 263
 Gold, L. 11, 266
 Gold, L. 11, 270
 Gold, L. 11, 272
 Gold, L. 11, 274
 Gold, L. 11, 276
 Gold, L. 11, 278
 Gold, L. 11, 280
 Gold, L. 11, 282
 Gold, L. 11, 284
 Gold, L. 11, 286
 Gold, L. 11, 288
 Gold, L. 11, 290
 Gold, L. 11, 292
 Gold, L. 11, 294
 Gold, L. 11, 296
 Gold, L. 11, 298
 Gold, L. 11, 300
 Gold, L. 11, 302
 Gold, L. 11, 304
 Gold, L. 11, 306
 Gold, L. 11, 308
 Gold, L. 11, 310
 Gold, L. 11, 312
 Gold, L. 11, 314
 Gold, L. 11, 316
 Gold, L. 11, 318
 Gold, L. 11, 320
 Gold, L. 11, 322
 Gold, L. 11, 324
 Gold, L. 11, 326
 Gold, L. 11, 328
 Gold, L. 11, 330
 Gold, L. 11, 332
 Gold, L. 11, 334
 Gold, L. 11, 336
 Gold, L. 11, 338
 Gold, L. 11, 340
 Gold, L. 11, 342
 Gold, L. 11, 344
 Gold, L. 11, 346
 Gold, L. 11, 348
 Gold, L. 11, 350
 Gold, L. 11, 352
 Gold, L. 11, 354
 Gold, L. 11, 356
 Gold, L. 11, 358
 Gold, L. 11, 360
 Gold, L. 11, 362
 Gold, L. 11, 364
 Gold, L. 11, 366
 Gold, L. 11, 368
 Gold, L. 11, 370
 Gold, L. 11, 372
 Gold, L. 11, 374
 Gold, L. 11, 376
 Gold, L. 11, 378
 Gold, L. 11, 380
 Gold, L. 11, 382
 Gold, L. 11, 384
 Gold, L. 11, 386
 Gold, L. 11, 388
 Gold, L. 11, 390
 Gold, L. 11, 392
 Gold, L. 11, 394
 Gold, L. 11, 396
 Gold, L. 11, 398
 Gold, L. 11, 400
 Gold, L. 11, 402
 Gold, L. 11, 404
 Gold, L. 11, 406
 Gold, L. 11, 408
 Gold, L. 11, 410
 Gold, L. 11, 412
 Gold, L. 11, 414
 Gold, L. 11, 416
 Gold, L. 11, 418
 Gold, L. 11, 420
 Gold, L. 11, 422
 Gold, L. 11, 424
 Gold, L. 11, 426
 Gold, L. 11, 428
 Gold, L. 11, 430
 Gold, L. 11, 432
 Gold, L. 11, 434
 Gold, L. 11, 436
 Gold, L. 11, 438
 Gold, L. 11, 440
 Gold, L. 11, 442
 Gold, L. 11, 444
 Gold, L. 11, 446
 Gold, L. 11, 448
 Gold, L. 11, 450
 Gold, L. 11, 452
 Gold, L. 11, 454
 Gold, L. 11, 456
 Gold, L. 11, 458
 Gold, L. 11, 460
 Gold, L. 11, 462
 Gold, L. 11, 464
 Gold, L. 11, 466
 Gold, L. 11, 468
 Gold, L. 11, 470
 Gold, L. 11, 472
 Gold, L. 11, 474
 Gold, L. 11, 476
 Gold, L. 11, 478
 Gold, L. 11, 480
 Gold, L. 11, 482
 Gold, L. 11, 484
 Gold, L. 11, 486
 Gold, L. 11, 488
 Gold, L. 11, 490
 Gold, L. 11, 492
 Gold, L. 11, 494
 Gold, L. 11, 496
 Gold, L. 11, 498
 Gold, L. 11, 500
 Gold, L. 11, 502
 Gold, L. 11, 504
 Gold, L. 11, 506
 Gold, L. 11, 508
 Gold, L. 11, 510
 Gold, L. 11, 512
 Gold, L. 11, 514
 Gold, L. 11, 516
 Gold, L. 11, 518
 Gold, L. 11, 520
 Gold, L. 11, 522
 Gold, L. 11, 524
 Gold, L. 11, 526
 Gold, L. 11, 528
 Gold, L. 11, 530
 Gold, L. 11, 532
 Gold, L. 11, 534
 Gold, L. 11, 536
 Gold, L. 11, 538
 Gold, L. 11, 540
 Gold, L. 11, 542
 Gold, L. 11, 544
 Gold, L. 11, 546
 Gold, L. 11, 548
 Gold, L. 11, 550
 Gold, L. 11, 552
 Gold, L. 11, 554
 Gold, L. 11, 556
 Gold, L. 11, 558
 Gold, L. 11, 560
 Gold, L. 11, 562
 Gold, L. 11, 564
 Gold, L. 11, 566
 Gold, L. 11, 568
 Gold, L. 11, 570
 Gold, L. 11, 572
 Gold, L. 11, 574
 Gold, L. 11, 576
 Gold, L. 11, 578
 Gold, L. 11, 580
 Gold, L. 11, 582
 Gold, L. 11, 584
 Gold, L. 11, 586
 Gold, L. 11, 588
 Gold, L. 11, 590
 Gold, L. 11, 592
 Gold, L. 11, 594
 Gold, L. 11, 596
 Gold, L. 11, 598
 Gold, L. 11, 600
 Gold, L. 11, 602
 Gold, L. 11, 604
 Gold, L. 11, 606
 Gold, L. 11, 608
 Gold, L. 11, 610
 Gold, L. 11, 612
 Gold, L. 11, 614
 Gold, L. 11, 616
 Gold, L. 11, 618
 Gold, L. 11, 620
 Gold, L. 11, 622
 Gold, L. 11, 624
 Gold, L. 11, 626
 Gold, L. 11, 628
 Gold, L. 11, 630
 Gold, L. 11, 632
 Gold, L. 11, 634
 Gold, L. 11, 636
 Gold, L. 11, 638
 Gold, L. 11, 640
 Gold, L. 11, 642
 Gold, L. 11, 644
 Gold, L. 11, 646
 Gold, L. 11, 648
 Gold, L. 11, 650
 Gold, L. 11, 652
 Gold, L. 11, 654
 Gold, L. 11, 656
 Gold, L. 11, 658
 Gold, L. 11, 660
 Gold, L. 11, 662
 Gold, L. 11, 664
 Gold, L. 11, 666
 Gold, L. 11, 668
 Gold, L. 11, 670
 Gold, L. 11, 672
 Gold, L. 11, 674
 Gold, L. 11, 676
 Gold, L. 11, 678
 Gold, L. 11, 680
 Gold, L. 11, 682
 Gold, L. 11, 684
 Gold, L. 11, 686
 Gold, L. 11, 688
 Gold, L. 11, 690
 Gold, L. 11, 692
 Gold, L. 11, 694
 Gold, L. 11, 696
 Gold, L. 11, 698
 Gold, L. 11, 700
 Gold, L. 11, 702
 Gold, L. 11, 704
 Gold, L. 11, 706
 Gold, L. 11, 708
 Gold, L. 11, 710
 Gold, L. 11, 712
 Gold, L. 11, 714
 Gold, L. 11, 716
 Gold, L. 11, 718
 Gold, L. 11, 720
 Gold, L. 11, 722
 Gold, L. 11, 724
 Gold, L. 11, 726
 Gold, L. 11, 728
 Gold, L. 11, 730
 Gold, L. 11, 732
 Gold, L. 11, 734
 Gold, L. 11, 736
 Gold, L. 11, 738
 Gold, L. 11, 740
 Gold, L. 11, 742
 Gold, L. 11, 744
 Gold, L. 11, 746
 Gold, L. 11, 748
 Gold, L. 11, 750
 Gold, L. 11, 752
 Gold, L. 11, 754
 Gold, L. 11, 756
 Gold, L. 11, 758
 Gold, L. 11, 760
 Gold, L. 11, 762
 Gold, L. 11, 764
 Gold, L. 11, 766
 Gold, L. 11, 768
 Gold, L. 11, 770
 Gold, L. 11, 772
 Gold, L. 11, 774
 Gold, L. 11, 776
 Gold, L. 11, 778
 Gold, L. 11, 780
 Gold, L. 11, 782
 Gold, L. 11, 784
 Gold, L. 11, 786
 Gold, L. 11, 788
 Gold, L. 11, 790
 Gold, L. 11, 792
 Gold, L. 11, 794
 Gold, L. 11, 796
 Gold, L. 11, 798
 Gold, L. 11, 800
 Gold, L. 11, 802
 Gold, L. 11, 804
 Gold, L. 11, 806
 Gold, L. 11, 808
 Gold, L. 11, 810
 Gold, L. 11, 812
 Gold, L. 11, 814
 Gold, L. 11, 816
 Gold, L. 11, 818
 Gold, L. 11, 820
 Gold, L. 11, 822
 Gold, L. 11, 824
 Gold, L. 11, 826
 Gold, L. 11, 828
 Gold, L. 11, 830
 Gold, L. 11, 832
 Gold, L. 11, 834
 Gold, L. 11, 836
 Gold, L. 11, 838
 Gold, L. 11, 840
 Gold, L. 11, 842
 Gold, L. 11, 844
 Gold, L. 11, 846
 Gold, L. 11, 848
 Gold, L. 11, 850
 Gold, L. 11, 852
 Gold, L. 11, 854
 Gold, L. 11, 856
 Gold, L. 11, 858
 Gold, L. 11, 860
 Gold, L. 11, 862
 Gold, L. 11, 864
 Gold, L. 11, 866
 Gold, L. 11, 868
 Gold, L. 11, 870
 Gold, L. 11, 872
 Gold, L. 11, 874
 Gold, L. 11, 876
 Gold, L. 11, 878
 Gold, L. 11, 880
 Gold, L. 11, 882
 Gold, L. 11, 884
 Gold, L. 11, 886
 Gold, L. 11, 888
 Gold, L. 11, 890
 Gold, L. 11, 892
 Gold, L. 11, 894
 Gold, L. 11, 896
 Gold, L. 11, 898
 Gold, L. 11, 900
 Gold, L. 11, 902
 Gold, L. 11, 904
 Gold, L. 11, 906
 Gold, L. 11, 908
 Gold, L. 11, 910
 Gold, L. 11, 912
 Gold, L. 11, 914
 Gold, L. 11, 916
 Gold, L. 11, 918
 Gold, L. 11, 920
 Gold, L. 11, 922
 Gold, L. 11, 924
 Gold, L. 11, 926
 Gold, L. 11, 928
 Gold, L. 11, 930
 Gold, L. 11, 932
 Gold, L. 11, 934
 Gold, L. 11, 936
 Gold, L. 11, 938
 Gold, L. 11, 940
 Gold, L. 11, 942
 Gold, L. 11, 944
 Gold, L. 11, 946
 Gold, L. 11, 948
 Gold, L. 11, 950
 Gold, L. 11, 952
 Gold, L. 11, 954
 Gold, L. 11, 956
 Gold, L. 11, 958
 Gold, L. 11, 960
 Gold, L. 11, 962
 Gold, L. 11, 964
 Gold, L. 11, 966
 Gold, L. 11, 968
 Gold, L. 11, 970
 Gold, L. 11, 972
 Gold, L. 11, 974
 Gold, L. 11, 976
 Gold, L. 11, 978
 Gold, L. 11, 980
 Gold, L. 11, 982
 Gold, L. 11, 984
 Gold, L. 11, 986
 Gold, L. 11, 988
 Gold, L. 11, 990
 Gold, L. 11, 992
 Gold, L. 11, 994
 Gold, L. 11, 996
 Gold, L. 11, 998
 Gold, L. 11, 1000
 Gold, L. 11, 1002
 Gold, L. 11, 1004
 Gold, L. 11, 1006
 Gold, L. 11, 1008
 Gold, L. 11, 1010
 Gold, L. 11, 1012
 Gold, L. 11, 1014
 Gold, L. 11, 1016
 Gold, L. 11, 1018
 Gold, L. 11, 1020
 Gold, L. 11, 1022
 Gold, L. 11, 1024
 Gold, L. 11, 1026
 Gold, L. 11, 1028
 Gold, L. 11, 1030
 Gold, L. 11, 1032
 Gold, L. 11, 1034
 Gold, L. 11, 1036
 Gold, L. 11, 1038
 Gold, L. 11, 1040
 Gold, L. 11, 1042
 Gold, L. 11, 1044
 Gold, L. 11, 1046
 Gold, L. 11, 1048
 Gold, L. 11, 1050
 Gold, L. 11, 1052
 Gold, L. 11, 1054
 Gold, L. 11, 1056
 Gold, L. 11, 1058
 Gold, L. 11, 1060
 Gold, L. 11, 1062
 Gold, L. 11, 1064
 Gold, L. 11, 1066
 Gold, L. 11, 1068
 Gold, L. 11, 1070
 Gold, L. 11, 1072
 Gold, L. 11, 1074
 Gold, L. 11, 1076
 Gold, L. 11, 1078
 Gold, L. 11, 1080
 Gold, L. 11, 1082
 Gold, L. 11, 1084
 Gold, L. 11, 1086
 Gold, L. 11, 1088
 Gold, L. 11, 1090
 Gold, L. 11, 1092
 Gold, L. 11, 1094
 Gold, L. 11, 1096
 Gold, L. 11, 1098
 Gold, L. 11, 1100
 Gold, L. 11, 1102
 Gold, L. 11, 1104
 Gold, L. 11, 1106
 Gold, L. 11, 1108
 Gold, L. 11, 1110
 Gold, L. 11, 1112
 Gold, L. 11, 1114
 Gold, L. 11, 1116
 Gold, L. 11, 1118
 Gold, L. 11, 1120
 Gold, L. 11, 1122
 Gold, L. 11, 1124
 Gold, L. 11, 1126
 Gold, L. 11, 1128
 Gold, L. 11, 1130
 Gold, L. 11, 1132
 Gold, L. 11, 1134
 Gold, L. 11, 1136
 Gold, L. 11, 1138
 Gold, L. 11, 1140
 Gold, L. 11, 1142
 Gold, L. 11, 1144
 Gold, L. 11, 1146
 Gold, L. 11, 1148
 Gold, L. 11, 1150
 Gold, L. 11, 1152
 Gold, L. 11, 1154
 Gold, L. 11, 1156
 Gold, L. 11, 1158
 Gold, L. 11, 1160
 Gold, L. 11, 1162
 Gold, L. 11, 1164
 Gold, L. 11, 1166
 Gold, L. 11, 1168
 Gold, L. 11, 1170
 Gold, L. 11, 1172
 Gold, L. 11, 1174
 Gold, L. 11, 1176
 Gold, L. 11, 1178
 Gold, L. 11, 1180
 Gold, L. 11, 1182
 Gold, L. 11, 1184
 Gold, L. 11, 1186
 Gold, L. 11, 1188
 Gold, L. 11, 1190
 Gold, L. 11, 1192
 Gold, L. 11, 1194
 Gold, L. 11, 1196
 Gold, L. 11, 1198
 Gold, L. 11, 1200
 Gold, L. 11, 1202
 Gold, L. 11, 1204
 Gold, L. 11, 1206
 Gold, L. 11, 1208
 Gold, L. 11, 1210
 Gold, L. 11, 1212
 Gold, L. 11, 1214
 Gold, L. 11, 1216
 Gold, L. 11, 1218
 Gold, L. 11, 1220
 Gold, L. 11, 1222
 Gold, L. 11, 1224
 Gold, L. 11, 1226
 Gold, L. 11, 1228
 Gold, L. 11, 1230
 Gold, L. 11, 1232
 Gold, L. 11, 1234
 Gold, L. 11, 1236
 Gold, L. 11, 1238
 Gold, L. 11, 1240
 Gold, L. 11, 1242
 Gold, L. 11, 1244
 Gold, L. 11, 1246
 Gold, L. 11, 1248
 Gold, L. 11, 1250
 Gold, L. 11, 1252
 Gold, L. 11, 1254
 Gold, L. 11, 1256
 Gold, L. 11, 1258
 Gold, L. 11, 1260
 Gold, L. 11, 1262
 Gold, L. 11, 1264
 Gold, L. 11, 1266
 Gold, L. 11, 1268
 Gold, L. 11, 1270
 Gold, L. 11, 1272
 Gold, L. 11, 1274
 Gold, L. 11, 1276
 Gold, L. 11, 1278
 Gold, L. 11, 1280
 Gold, L. 11, 1282
 Gold, L. 11, 1284
 Gold, L. 11, 1286
 Gold, L. 11, 1288
 Gold, L. 11, 1290
 Gold, L. 11, 1292
 Gold, L. 11, 1294
 Gold, L. 11, 1296
 Gold, L. 11, 1298
 Gold, L. 11, 1300
 Gold, L. 11, 1302
 Gold, L. 11, 1304
 Gold, L. 11, 1306
 Gold, L. 11, 1308
 Gold, L. 11, 1310
 Gold, L. 11, 1312
 Gold, L. 11, 1314
 Gold, L. 11, 1316
 Gold, L. 11, 1318
 Gold, L. 11, 1320
 Gold, L. 11, 1322
 Gold, L. 11, 1324
 Gold, L. 11, 1326
 Gold, L. 11, 1328
 Gold, L. 11, 1330
 Gold, L. 11, 1332
 Gold, L. 11, 1334
 Gold, L. 11, 1336
 Gold, L. 11, 1338
 Gold, L. 11, 1340
 Gold, L. 11, 1342
 Gold, L. 11, 1344
 Gold, L. 11, 1346
 Gold, L. 11, 1348
 Gold, L. 11, 1350
 Gold, L. 11, 1352
 Gold, L. 11, 1354
 Gold, L. 11, 1356

AUTHOR INDEX (Continued)

- Nordling, K.I. 11,553
Norton, C.J. 11,577
Novototskii-Vlasov, Yu. F. 11,351
Noyce, R.N. 11,510
Nussbaum, A. 11,370, 11,391
Oakes, J.B. 11,595
Okazaki, A. 11,343
Ol'shanskaia, N.I. 11,344
Olson, F.A. 11,548
Orris, E. 11,495
Otte, H.E. 11,277
Owen, D.H. 11,311
Owen, P.L. 11,618
Paces, J. 11,406
Pallas, C.E. 11,582
Pamplin, B.R. 11,371
Pankove, J.I. 11,480, 11,503
Pao, Y.H. 11,526
Park, J.G. 11,358
Parker, R.G. 11,310
Parmenter, R.H. 11,331, 11,383
Partridge, M.F. 11,618
Pastushchuk, N.S. 11,454
Pataki, G. 11,484
Pátek, K. 11,446
Paterson, M.S. 11,280
Paul, W. 11,362
Pedersen, B. 11,424
Peizer, E. 11,586
Pellin, R.A. 11,299
Peretti, E.A. 11,249, 11,250
Pershan, P.S. 11,413, 11,414
Petin, G.P. 11,346
Petrucelly, V. 11,529
Peyssou, J. 11,313
Pfeifer, F. 11,519
Phillips, E.A. 11,461
Pick, R. 11,392
Pikus, G.E. 11,420
Pincus, P. 11,410
Pittman, Jr., G.F. 11,518
Pokrovskaya, S.V. 11,351
Pomerantz, M. 11,407
Popova, S.V. 11,360
Potter, J.B. 11,542
Potts, R.R. 11,623
Powell, R.L. 11,403
Prager, H.J. 11,571
Presnov, V.A. 11,372
Pugh, E.N. 11,323
Pyle, R. 11,252
Quinn, H.F. 11,308, 11,327
Radautsan, S.I. 11,256, 11,258, 11,270
Randise, D. 11,576
Reed, R.S. 11,594
Reeser, G.A. 11,520
Regel', A.R. 11,272, 11,332, 11,357, 11,373
Reggia, F. 11,561
Reich, A.D. 11,516
Remeika, J.P. 11,401
Resnikoff, M. 11,526
Riddle, G.C. 11,534
Ripps, H. 11,588
Ritz, U.H. 11,635
Roberts, D.H. 11,530
Robertson, D.W. 11,477
Robertson, H.M. 11,501
Robertson, W.J. 11,597
Rodriguez, C. 11,585
Rohrer, H. 11,514
Romanenko, V.N. 11,253
Root, C.D. 11,498
Rose-Innes, A.C. 11,385
Roy, R. 11,565
Rozenstein, L.D. 11,456
Rubinoff, M. 11,567
Ruck, H.C. 11,584
Rudisill, J.E. 11,404
Rueda, F. 11,285
Ryan, F.M. 11,355
Ryan, R.D. 11,589
Rychtarik, V. 11,487
Ryvkin, S.M. 11,339, 11,457
Rzhanov, A.V. 11,351
Sadagopan, V. 11,246
Sakai, E. 11,636
Sakiotis, N.G. 11,605
Sallo, J.S. 11,306, 11,328
Salow, H. 11,494
Salzberg, C.D. 11,435
Samuels, L.E. 11,323
Sarace, J.C. 11,291
Savarin, A. 11,548
Savelli, M. 11,392
Schmidt, H. 11,588
Schmidt, W.C. 11,623
Schmidt-Tiedemann, K.J. 11,353
Schnable, G.L. 11,326
Schnettler, F.J. 11,314
Schoen, M. 11,639
Schreiber, F. 11,544
Schulman, J.H. 11,638
Schwartz, R.S. 11,497
Schwarz, F. 11,630
Sebestyen, L.G. 11,608
Selwood, P.W. 11,398
Semerchan, A.A. 11,360
Sera, T. la. 11,439
Serdiuk, V.V. 11,439
Serin, B. 11,385
Shalimova, K.V. 11,442
Shanks, H.R. 11,378
Shchegolev, I.F. 11,427
Sheard, J. 11,336
Shekhmamet'ev, R.I. 11,450
Shevel, Jr., W.L. 11,303
Shih, C. 11,249, 11,250
Shil'shtein, S.Sh. 11,287
Shtrikman, S. 11,404
Sidles, P.H. 11,378
Sie, J.J. 11,552
Siegel, I.M. 11,588
Silsbee, R.H. 11,421
Simmons, B.D. 11,564
Simonyan, K. 11,504
Sirs, J.A. 11,631
Sitharama Rao, D.N. 11,455
Sixtus, K.J. 11,316
Sizer, T.R.H. 11,618
Skudnova, E.V. 11,269
Slade, B.N. 11,497
Sliker, T.R. 11,424
Smirnov, A.A. 11,247
Smith, A.C. 11,361
Smith, B.A. 11,265
Smith, G.E. 11,395
Smith, R.S. 11,307
Sokolova, V.I. 11,292
Soller, A.T. 11,466
Salon, L.R. 11,587
Sondaevskii, V.P. 11,339
Spencer, E.G. 11,408
Sperry, Jr., C.J. 11,585
Speyer, E. 11,517
Stavitskaia, T.S. 11,356
Steiger, W. 11,572
Stilbans, L.S. 11,356
Stoehr, H. 11,254
Stoudenheimer, R.G. 11,452
Suda, P. 11,406
Suemune, Y. 11,343
Sugaika, S. 11,276
Sulich, M. 11,308
Suozi, J.J. 11,556
Swenson, J.I. 11,328
Synorov, V.F. 11,372
Sysoeva, L.M. 11,356
Takacs, J. 11,608
Takhareva, N.K. 11,474
Talley, C.P. 11,301
Tauc, J. 11,334
Taylor, A. 11,476
Tetenbaum, S.J. 11,548
Thiele, D. 11,255
Thompson, M.W. 11,295
Thornton, W.T. 11,637
Thuy, H.J. 11,499
Tikhonova, E.A. 11,247
Tilly, G.P. 11,324
Tlusty, J. 11,624
Todd, C.D. 11,644
Toma, B. 11,257
Tonking, F.G. 11,589
Trakna, R.E. 11,475
Travina, T.S. 11,442
Treskina, M.N. 11,363, 11,366
Troelstra, S.A. 11,304
Tyler, D.C. 11,599
Uhlir, Jr., A. 11,490
Ulrich, W. 11,264
Umanskii, Ya.S. 11,287
Ur, H. 11,563
van Amstel, J.J.A.P. 11,500
van Bueren, H.G. 11,284
van Laar, J.A.W. 11,304
van Uiter, L.G.G. 11,305, 11,320, 11,321
Vartanyan, A.T. 11,456
Vassiliev, A. 11,313
Vereshchagin, L.F. 11,360
Viatkina, A.V. 11,275
Vitovskii, N.A. 11,339
Vodop'ianov, K.A. 11,344
Vogel, R.E. 11,278
Von Fleck, J.H. 11,415
Varozhtsov, B.I. 11,344
Wachowski, H.M. 11,551
Ward, J. 11,591
Watkins, G.D. 11,281
Watkins, H. 11,471
Watkins, J. 11,533
Webster, H.F. 11,394
Webster, Jr., W.M. 11,505
Wei, C.T. 11,468
Weinberg, I. 11,412
Weisberg, L.R. 11,340
Weise, J.R. 11,252
Weiss, H. 11,396
Weiszbarg, J. 11,445
Wernick, J.H. 11,251
Wertheim, G.K. 11,417
West, E.J. 11,638
Whelehan, J.J. 11,545
White, R.L. 11,419
Whittaker, J.B. 11,367
Wickersheim, K.A. 11,438
Willens, R.H. 11,259
Winkler, U. 11,377
Winship, R.L. 11,645
Winter, J.M. 11,410, 11,425
Woessner, D.E. 11,426
Wolf, W.P. 11,402
Wolfe, I.W. 11,397
Wolff, H.H. 11,627
Woodbury, J.R. 11,628
Woolley, J.C. 11,265, 11,271, 11,335, 11,371
Wooten, F. 11,459
Yokota, R. 11,636
Zakharchenya, B.P. 11,431
Zaret, M.M. 11,588
Zavadovskaia, E.K. 11,363, 11,366
Zeleny, J. 11,625
Zemel, J.N. 11,354
Zerbst, M. 11,453
Zhdanov, V.A. 11,279
Zumino, B. 11,382